INTRODUCTION

This document is intended for use with "Keeping the books for environmental systems: An Emergy Analysis of West Virginia" by Daniel Campbell, Maria Meisch, Tom DeMoss, John Pomponio, and Patricia Bradley published in Environmental Monitoring and Assessment Volume 94: 217-230, 2004 (Campbell et al. 2004). It is described in that article as supporting data and materials residing at http://www.epa.gov/aed/research/desupp3.html.

The references, data sources, and appendices given in this document will be part of a USEPA research report titled "Environmental Accounting Using Emergy: Evaluation of the State of West Virginia" by D.E. Campbell, S.L. Brandt-Williams, and M. E.A. Meisch that will be published later this year (2004). The data, sources, and calculations used to obtain the numbers found in Campbell et al. (2004) are given in the appendices that follow. In the intervening year between completion of Campbell et al. (2004) and the completion of the aforementioned US EPA Research Report errors were corrected and calculations were refined; therefore, some of the numbers in the technical report and on this web site are different from the numbers in Campbell et al. (2004). A list of the major changes follows:

(1) In the calculations in Campbell et al. (2004) a transformity of 196,000 sej/J was used for electricity and 156,000 sej/J for hydroelectricity these values have been replaced using broader averages from Odum (1996) and are now 170,400 for electricity and 120,300 sej/J for hydroelectricity. To obtain these averages adjust the values in Odum (1996) to the 9.26 E+24 sej/y planetary baseline. As a result all numbers that depended on the emergy of electricity used or exported are somewhat different here than in Campbell et al. 2004.

(2) The 1997 emergy to dollar ratio for the United States was recalculated and found to be 1.20 x 10^{12} sej/$ rather than 1.22 x 10^{12} sej/$. This change was due to the lower transformity of electricity used to estimate nuclear energy's emergy contribution to the emergy resource base for the United States. The transformity of coal electricity was used to estimate the emergy contribution of nuclear electricity. As a result of the change in the emergy to money ratio for 1997, all the estimates of emdollar values given in Campbell et al. (2004) must be multiplied by 1.01667 to obtain the numbers in this posting given that no other factor has intervened to cause a change in the emergy estimate for an item.

(3) The geopotenial energy in runoff absorbed in the state was incorrectly calculated in Campbell et al. (2004), because the energy absorbed was determined relative to sea level rather than to the lowest point where the river water leaves the state. When this error was corrected the geopotential emergy absorbed decreased from 18 E+20 sej/y to 16 E+20 sej/y.

(4) The transformity of agricultural products in this posting was determined using a weighted average based on mass. The greater mass of hay lowers the overall transformity from that used in Campbell et al. (2004).

(5)The factor 2:1 used to estimate raw material for the aluminum industry was based on alumina. In fact the estimate should have been 4:1 for bauxite. The correction is made in these tables.

(6) The rule used to estimate imported service was changed. The ratio of the state's per capita income to the national average per capita income was used to estimate the quantity of potentially imported services that would probably be imported when a state's per capita income is less than the national average. As a result our estimate of West Virginia's imported services increased from 4 billion to 6.2 billion dollars.

(7)As a result of the previous changes the emergy to dollar ratio for West Virginia changed very slightly from 5.72 to 5.78 E+12 sej /$.

(8) Tourism should have been an entry on the exports table rather than the imports table. It is entered this way in the technical report.
(9) Slight changes in the numbers in the summary and indices tables follow as a consequence of these changes.
(10) The conclusions and relationships in Campbell et al. (2004) remain unchanged by the corrections made to the analysis as a result of further examination and criticism over the past year. The above list of changes may not be exhaustive since there are many possibilities for miscalculations and errors in such a large analysis. If any visitor to this site finds an error in or has a question about the information posted here they may contact me at Campbell.dan@epa.gov.

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Iron Ore Price
http://www.indiainfoline.com/sect/iror/db01.html
Aluminum Price
http://www.amm.com/ref/alum.HTM
(37) For states with an international port of entry data on imports can be found at
http://www.ustr.gov/outreach/states/westva.pdf Office of the United States Trade Representative.
Also see http://dataweb.usitc.gov/scripts/user_set.asp for West Virginia Exports
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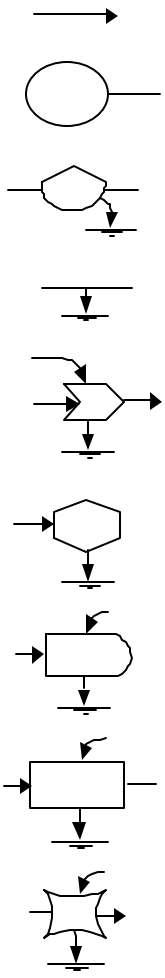
Appendix A.

Primary Symbols of the Energy Systems Language



Energy circuit A pathway whose flow is proportional to the storage or source upstream.

Source A forcing function or outside source of energy delivering forces according to a program controlled from outside.

Tank A compartment or state variable within the system storing a quantity as the balance of inflows and outflows.

Heat sink Dispersion of potential energy into heat accompanies all real transformation processes and storages . This energy is no longer usable by the system.

Interaction Interactive intersection of two pathways coupled to produce an outflow in proportion to a function of both; a work gate.

Consumer An autocatalyticunit that transforms energy, stores it and feeds it back to improve inflow.

Producer Unit that collects and transforms low-quality energy under the control of high quality flows.

Box Miscellaneous symbol to use for whatever unit or function is needed.

Switching Action A symbol that indicates one or more switching actions controlled by a logic program.

Figure A1. Primary symbols of the Energy Systems Language.

Appendix B.

Sources, Adjustment, and Calculation of Transformities

B1. Information sources for the emergy per unit values used in this report. The note number links the emergy per unit values listed in this table to the values used in Tables 4-8. The emergy per unit values used in Table B1.1 are given to three significant figures and shown for the 9.44, 9.26 and 15.83 E+24 sej/y baselines. Values are transformities with units of sej/J except where other units are noted. For example where emergy per unit mass is given a (g) for mass is noted next to the item and the units are sej/g. The emergy per unit of education level is sej per individual and the emergy to dollar ratio (sej/$) is used for services. Table B3.1 gives the factors used to convert one baseline to another. The 9.44 baseline was used by Odum (1996) and revised to the 9.26 baseline by Campbell (2000a). The 9.44 values are reported, because many transformities in the older literature are given relative to this baseline.

Table B1.1 The values and sources for transformities and specific emergies used in this report.

Note	Item	Source of transformity or specific emergy calculation	Emergy/unit 9.44	Emergy/unit 9.26	Emergy/unit 15.83
1	Incident solar radiation	(by definition)	1	1	1
2	Wind -	Odum (1996), p. 309	1496	1470	2.51E+03
3	Earth Cycle	Odum (1996), p. 309	34377	33700	5.76E+04
4	Rain, chemical potential	Odum (1996) Campbell (2003)	18200	18100	3.12E+04
5	Evapotranspiration,	Odum (1996) Campbell (2003)	18200	28100	4.80E+04
6	Rain, geo-potential, land	Odum (1996), p. 309	10488	10300	1.76E+04
7	Rain, geo-potential runoff	Odum (1996) (errata)	27764	27200	4.66E+04
8	Rivers, chemical	Odum (1996), Campbell (2003)	48459	50100	8.13E+04
9	Rivers, geo-potential	Odum (1996), p. 43	27764	27200	4.66E+04
10	Agricultural Products	Brandt-Williams (2001)		63000	
	A weighted average of:	See B3 #7.			
10	Hay (0.86)	See B3 #7.		40100	6.86E+4
10	Grains, fruits, tobacco	See B3 #7.		207600	3.55E+5
11	Livestock (poultry)	Odum et al. (1998)	7.36E+05	792000	1.23E+06
	Beef cattle	See B3 #7.		680000	1.14E+06
12	Fish Production -	Odum et al. (1998a)	2.0E+06	1960000	3.35E+06
13	Hydroelectricity -	Odum (1996), p. 186&305	1.23E+05	120300	2.06E+05
14	Net Timber Growth -	Tilley (1999), p.150	2.10E+04	20600	3.52E+04
15	Timber Harvest service	Tilley (1999)	7.00E+04	68700	1.17E+05
16	Ground water	Odum et al. (1998a)	1.62E+05	159000	2.72E+05
17	Coal	Odum (1996), p. 310	4.00E+04	39200	6.71E+04
19	Natural Gas	Odum (1996), p. 311	4.80E+04	47100	8.05E+04
21	Petroleum – Crude oil,	Odum (1996), p. 311	5.40E+04	53000	9.06E+04
23	Electricity -	Odum (1996), p. 305& 311	173681	170400	2.91E+05

Table B1.1 continued.

Note	Item	Source of transformity or specific emergy calculation	Emergy/unit 9.44	Emergy/unit 9.26	Emergy/unit 15.83
25	Clay Odum (1996) (g)	Odum (1996)	2E+09	1.96E+9	3.35E+09
26	Sand and Gravel (g)	(B3 # 5)	1.33E+9	1.31 E9	2.24E+09
27	Limestone (g)	Odum (1996)	1.0 E9	9.81 E8	1.68E+09
28	Sandstone (g)	Odum (1996)	1.0 E9	9.81 E8	1.68E+09
29	Erosion, topsoil	Odum (1996)	74000	72600	1.24E+05
31	Petroleum fuels	Odum (1996), p. 186	6.60E+04	64700	1.11E+05
33	Iron Ore	Odum (1996)	6.20E+07	60815800	1.04E+08
34	Aluminum ore, bauxite,	Odum (1996)	1.50E+07	14700000	2.52E+07
35	Services in goods ($)	1997 ($)		1.2 E+12	
36	Materials in Goods	(Table B2.1)			
44	Steel (g)	Brown and Buranakarn (2000)	3.45E+09	3380000000	5.79E+09
49	Standing Biomass	(B3 #3)		28200	4.82E+04
53	People (per individual)	Odum (1988, 1996)			
	Preschool (ind.)		3.40E+16	3.E+16	5.70E+16
	School (ind.)		9.40E+16	9.E+16	1.58E+17
	College Grad (ind.)		2.80E+17	3.E+17	4.70E+17
	Post-College (ind.)		1.31E+18	1.E+18	2.20E+18
	Elderly (65+) (ind.)	(B3 #4)		1.69E+17	2.89E+17
	Public Status (ind.)		3.93E+18	4.E+18	6.59E+18
	Legacy (ind.)		7.85E+18	8.E+18	1.32E+19
NA	Net Timber Prod.	Tilley (1999) p.150	1.10E+04	10800	1.84E+04
NA	Aluminum (g)	Brown and Buranakarn (2000)	1.25E+10	12300000000	2.10E+10

B2. Estimation of Transformities for the SCTG Commodity Classes.

A transformities and specific emergies for each SCTG commodity classes were determined by averaging items within the class for which transformities were known. For classes where no transformities were available the transformity of the raw materials was used as a first order estimate. Transformities for the SCTG commodity class codes are given below as estimated from the transformities of the items listed. See Appendix D Table D1.1 for a definition of the items represented in the SCTG Class Code numbers. Emergy per unit is relative to the 9.26 baseline.

Table B2.1 Transformities and Specific Emergies for the SCTG Commodity Classes.

Class Code	Items in Class Average	Transformity sej/J	Spec. Emergy sej/g
1	Avg. poultry and cattle, Odum et al. (1987) Brandt-Williams (2001)	439,300	
2	Avg. wheat, grain corn, rice, oats, sorghum, Odum et al. (1987) Brandt-Williams (2001)	181,800	
3	Avg. soybeans, cotton, pecans, cabbages, oranges, etc. Odum et al. (1987) Brandt-Williams (2001)	233,400	
4	forage Ulgiati et al. (1994) Cornstalks & wool Odum (1996), eggs Brandt-Williams (2001)	1.22 E6	

Table B2.1 continued.

Class Code	Items in Class Average	Transformity sej/J	Spec. Emergy sej/g
5	meat (veal, mutton), shrimp, Odum (1996).	3.27 E6	
6	use flour (wheat + energy to process)	18,1800	
7	sugar, palm oil and cacao from Odum et al. (1986b), milk Brandt-Williams (2001).	1.12 E6	
8	use ethanol and avg. 10% alcohol by volume for beer and wine,, Odum (1996).	58,900	
9	use tobacco, Scatena et al. (2002).	650,000	
10	use limestone Odum (1996).		9.81 E8
11	use sand, this study.		1.31 E9
12	use granite rocks Odum (1996).		4.91 E8
13	use clay, Odum (1996).		1.96 E9
14	use ore rocks, iron, alumina, copper, nickel, zinc Odum (1996).		2.71 E9
15	Use coal Odum (1996).	39,200	
17	use crude oil, petroleum fuels Odum (1996).	64,700	
18	use petroleum fuels Odum (1996).	64,700	
19	use fuel oil Odum (1996)	64,700	
20	use hydrated lime, caustic soda, diatomite, and sulfuric acid Odum et al. (2000b)		2.75 E9
21	Pharmaceutical and biological products (use chemicals as feedstock)		2.75 E9
22	Fertilizer from Brandt-Williams (2001) and Odum (1996).		2.99 E9
23	insecticide (Brown and Arding 1991, paint and glue from Buranakarn (1998).		9.90 E9
24	(plastic, tires, etc,) Odum et al. (1987)		2.71 E9
25	use avg. softwood and hardwood logs Odum (1996).	19,600	
26	use wood chips, lumber, particle board, plywood, Buranakarn (1998).		1.49 E 9
27	(use avg. wood pulp, paper, paper board), Tilley (1999)	139,800	
28	(bags, packing, toilet paper, envelopes, wallpaper) Tilley (1999)	167,400	
29	Paper from Tilley (1999) Ink assumed similar to other chemical preparations.		4.95 E9
30	use avg. of textiles and leather Odum et al. (1987)	7.18 E6	
31	use avg. ceramics, glass flat and float, brick, concrete, Buranakarn (1998)		3.09 E9
32	Avg. iron , steel, copper, aluminum Buranakarn (1998), Al 1/2 weight in avg.		5.91 E9
33	Assume articles of metal have similar transformities to the unformed metal.		5.91 E9
34	Machinery non electrical, Odum et. al. (1987)		7.76 E9
35	assume the transformity for machinery applies Odum et. al. (1987)		7.76 E9
36	assume the transformity for machinery applies Odum et. al. (1987) .		7.76 E9
37	assume the transformity for machinery applies Odum et. al. (1987)		7.76 E9
38	assume the transformity for machinery applies Odum et. al. (1987)		7.76 E9
39	(household furniture, lamps, mattresses) use hardwood, Buranakarn (1998)		2.89 E9
40	miscellaneous manufactured goods		1.61 E9
41	Tire waste, wood waste, slag. Buranakarn (1998)		2.16 E9
43	corn and steel for groceries and hardware		6.32 E9

B3. Calculation of New or Revised Transformities.

In all cases transformity is determined by dividing the emergy (sej or sej/y) required for product or service by the energy (J or J/y) in the product or service.

No. In this section, number simply refers to the new transformity calculations.

1 **Calculation of Transformity for Forest Growth in West Virginia**

Evaportranspiration	3.67E+21 sej/y
Net Timber Growth (includes mortality)	2.10E+17 J/y
	17496 sej/J

2 **Calculation of Transformity for Forest Net Primary Production in West Virginia**

Evaportranspiration	3.67E+21 sej/y
Net Primary Production of Timber	3.09E+17 J/y
	11858 sej/J

3 **Calculation of Transformity for Forest Storage in West Virginia**

Evaportranspiration	3.67E+21 sej/y
Average age of a tree	80
Forest Storage	1.04E+19 J
Emergy to produce the forest	2.94E+23 sej
Transformity of biomass in 80 yr-old trees	28200 sej/J

4 **Calculation of the Transformity of the Elderly in West Virginia**

This estimate was based on the education level that elderly individuals in 1990 attained in 1930. The 1990 census showed that 8.75% of the population was 65-74 years old and that 6.24% of the population was 75 years and older.

In 1930, 86% of 14-15 year olds were in school. 20% of 18-20 year olds were also in school.
If the average age at graduation was 18 and the same pattern holds, around 20% of the high school age students graduated. In 1940, 4% of 21-41 year olds were enrolled in school. Assuming that these students graduated and that they indicate the average status of those born from 1915 to 1920 about 4% of the 1990 elderly aged 70 to 75 were college graduates.
The educational status of West Virginia in 1990 was estimated as follows: (1) 80% of 65 and older attended school but left between age 15 and age 18. (2) 20% were high school graduates and had some college and 4% were college graduates with some graduate work.

Education Status of Elderly individual	Individuals	Transformity sej/ind.
Total # 65 years or older in 1990	159518	
school (80%)	127615	9.2E+16
college (16%)	25523	2.7E+17
post-college (4%)	6381	1.3E+18
Emergy of all elderly individuals sej	2.69E+22	

Transformity of the elderly in West Virginia. **1.7 E+17 sej/ind.**

5 **Transformity for Sand from Sandstone** % SiO2

Sandstone Composition from Rosler and Lange (1972) and Degens (1965). Assume complete weathering to

quartz.	
Arkose sandstone (California	61.6
Glauconite sandstone (Switzerland)	78.34
Sandstone	79.63
	73.19
Assume loss of 25% of mass on weathering	0.75
Transformity of sand stone	1.00E+09
Transformity of sand from weathered sandstone based on mass concentration (1.0E9/0.75)	1.33E+09
Transformity of sand on the 9.26 baseline (X 0.981)	**1.31E+09**

6 **Transformity for Electricity from Nuclear Power**

Odum (1996) p. 50, Uranium ore 1.88E9 sej/g = 1.84E+09 sej/g on the 9.26 baseline

Odum (1996) p. 154, From evaluation of Lapp (1991) use the figure, on p. 154.

Item	sej/y	Source
Emergy from the economy	9.128E+23	Lapp (1991)
Emergy from the environment	4.90E+22	Lapp (1991)
Emergy from uranium ore	1.43E+23	Calculated below
Total Emergy	1.11E+24	Sum previous 3
On 9.26 baseline	1.08E+24	X 0.981
Joules of electricity generated	2.09E+19	Lapp (1991)

Transformity of nuclear electricity **5.19E+04** **sej/J**

Parameters		
kWh per kg U fuel	50000	Data source *(39)*
Kwh per year generated	5.80E+12	Lapp (1991)
tons U fuel used	1.16E+05	calculated
tons ore used	7.63E+07	calculated
Specific emergy Uranium ore	1.88E+09	Odum (1996)

Average uranium produced in the U.S.	Mine n=10	Data Source *(40)*
million lbs U_3O_8	3.49	
1000 MT U	1.35	
	Concentrate n=10	Data Source *(40)*
million lbs U3O8	4.26	
1000 MT U	1.64	

fraction U in U_3O_8 from data above	0.850703226	calculated
Stochiometry	0.847980998	calculated
Oxygen, MW 16	128	
Uranium, MW 238	714	
For $30 per pound U	All sources	(mining + leaching)
percent U_3O_8	0.17928	Data source *(41)*

7 **Revised Transformities for Agricultural Products.** Transformities for the agricultural products given in Brandt-Williams (2001) were recalculated with and without services using the 28100 sej/J as the transformity for evapotranspiration. The transformities without services included were used to determine the emergy of agricultural commodity flows.

Table B3.1 The factors needed to convert one planetary baseline to another.

To convert baseline, X	To baseline, Y	Multiply by
9.44	9.26	0.981
9.44	15.83	1.677
9.26	9.44	1.019
9.26	15.83	1.710
15.83	9.26	0.585
15.83	9.44	0.596

Table B3.2 Estimation of the emergy to dollar ratio in the United States for 1997 and 2000
Data and methods in Odum (1996) pp. 312-315 were used to extrapolate the emergy/$ ratio.

Year	Fossil fuel use J/y	Transformity	Nuclear J/y	Transformity	Comment
1997	8.483E+19	53000	7.048E+18	157000	The transformity for electricity from coal
2000	8.848E+19	53000	8.451E+18	157000	was used to estimate nuclear contribution.

	Fossil fuel use E+24 sej/y	Nuclear E+24 sej/y	Renewable x E+24 sej/y	Other E+24 sej/y	Total Emergy Use E+24 sej/y	GNP $	Emergy/$* sej/$
1997	4.50	1.11	2.10	1.87	9.57	7.95E+12	1.20E+12
2000	4.69	1.33	2.10	1.87	9.99	9.31E+12	1.07E+12

* These emergy to money ratios are slightly different from the value used in Campbell et al. 2004a, because the earlier numbers were not corrected to the 9.26 baseline.

Appendix C

Calculation of Energy and Economic Values Used to Determine the 1997 Energy and Emergy Accounts for West Virginia

C1 Notes for Table 4 – Annual Renewable Resources and Production in 1997.

The numbers in parentheses and italics refer to data sources given above. The notation E+3 or E+3 = 10^3.

Note

Area 6.2362 E+10 m2
Total land area of the state.

1 **Solar Energy** Received **3.074E+20 J/y**
Absorbed **2.644E+20 J/y**

Solar energy received (J) = (avg. insolation)(area)(365 day/y)(4186 J/kcal)
Solar energy absorbed = (received) (1-albedo)
The average insolation and albedo were obtained from the NASA website (10) referenced in sources. Eleven one-degree lat. by one-degree long. sectors covering the state were averaged.

	kWh/m2/y	J/m2/y	Joules/y
Solar energy received over the state	1369.414	4.93E+09	3.07436E+20
Solar energy absorbed by the state	1177.696	4.24E+09	2.64395E+20

2 **Kinetic Energy of Wind Used at the Surface** **3.58E+17 J/y**
Wind energy = (density)(drag coeff.)(geostrophic wind velocity)^3(area)(sec/year)

Calculated in Odum (1999) "Evaluating Landscape Use of Wind Kinetic Energy". The wind velocity used was a long-term average of four West Virginia stations in 1993 (11). The common drag coefficient is about 1.0E-3 for ordinary winds of 10 m/s or less over water (Miller 1964). Winds over land are about 0.6 of the wind velocity that the pressure system would generate in the absence of friction and the geostrophic dra

air density	1.3 kg/m3
wind velocity	6.98 mph
wind velocity (metric)	3.12 m/s
Geostrophic wind	5.2 m/s
drag coeff.	1.00E-03
area	6.2362 E+10 m2
sec / year	3.14E+07

3 **Earth Cycle Energy** **1.39E+17 J/y**
Earth cycle energy (steady-state uplift balanced by erosion) =
(land area)(heat flow/area)
The heat flow per area is an average of nine wells throughout the state.
of West Virginia *(12)*.
Area 6.2362 E+10 m2

Heat flow/area	70.56 mW/m2
	2.23E+06 J/m2/yr

4 **Rain Chemical Potential** **3.30E+17 J/y**

Chemical potential energy in rain =
(area)(rainfall)(density water)(Gibbs Free Energy water relative to seawater)
Average annual rainfall based on a one hundred year average from the National Climatic Data Center *(13)*.

Area	6.2362 E+10 m2
Rainfall	1.1 m/y
Gibbs Energy	4.74 J/g
Density	1.00E+06 g/m3

5 **Chemical Potential Energy of Evapotranspiration** **1.56E+17** **J/y**

Chemical potential energy in evapotranspiration =
(Area in land use)(Evapotranspiration)(density)(Gibbs Free Energy per gram)
Forest Transpiration estimated as 0.85 (Odum et al. (1998) of pan evaporation data measured from 1965 to 1990 at the US Forest Service Station at Fernow, WV (Adams et al. 1993). Direct measurements of evapotranspiration at Fernow in 1998 were used to check the long-term pan evaporation data. *(14)*. Evapotranspiration rates for crops and pasture from Arnold and Williams (1985).

Forest Area	49265769639 m2
Forest Transpiration	5.59E-01 m/y
	1.00E+06 g/m3
	4.74 J/g
	1.30E+17 J/y
Pasture area	2139634331 m2
Evapotranspiration	0.7285 m/y
	7.39E+15 J/y
Crop area	2597767780 m2
Evapotranspiration	0.694 m/y
	8.55E+15 J/y
Non crop area	2814248429 m2
Evapotranspiration	0.7285 m/y
	9.72E+15 J/y
Total area	56817420179 m2
Urban & barren area (by difference)	5544313542 m2

6 **Geopotential Energy of Rain on Land** **3.66E+17 J/y**

Geo-potential energy of rain on land elevated above sea level=
(area)(mean elevation)(rainfall)(density)(gravity)
An area weighted average of rainfall and elevation by county was used to determine the geopotential energy of rain on land for a 30 year average rainfall in inches using GIS methods.

Table C1.1. Data used to determine the geopotential energy of rainfall.

County	Area m^2	Avg. elevation m.	30 y avg. rainfall in.	geopot. energy
Hancock	228191120	322.427524	37.38536	6.85386E+14
Brooke	240176944	314.537809	39	7.34128E+14
Ohio	281945344	335.586703	39	9.19469E+14
Marshall	807178112	348.82437	41.29286	2.89704E+15
Preston	1686139648	630.98804	50.8542	1.34817E+16
Morgan	595436736	276.183843	37.02715	1.51725E+15
Mononga.	947073856	404.950628	43.57846	4.16448E+15
Wetzel	934991488	360.850872	45.24491	3.80371E+15
Mineral	853182720	397.950762	35.54701	3.0073E+15
Berkeley	833351552	199.736011	37.40184	1.55124E+15
Marion	806174464	376.575944	44.14345	3.33926E+15
Tyler	674734592	293.881773	43.70897	2.15963E+15
Hampshire	1669929728	377.768439	35.88709	5.64111E+15
Jefferson	548594112	160.223237	37.32662	8.17519E+14
Pleasants	348228768	273.18179	42.34601	1.00376E+15
Harrison	1078628224	366.759651	44.31864	4.3686E+15
Taylor	454673568	415.159562	45.41841	2.13624E+15
Doddridge	829267712	335.091023	45.02627	3.11764E+15
Wood	975464832	243.702585	40.0934	2.37491E+15
Ritchie	1174552960	297.039562	43.1418	3.75049E+15
Grant	1243197696	641.02717	38.34443	7.61415E+15
Barbour	887184064	521.134496	48.06692	5.53749E+15
Tucker	1090434304	857.48782	52.06758	1.2131E+16
Hardy	1513710208	537.310292	36.46919	7.39089E+15
Wirt	608199552	268.670655	42.90828	1.74707E+15
Lewis	1008180032	377.391402	46.69351	4.42679E+15
Randolph	2691785216	911.070648	53.8217	3.28891E+16
Upshur	918238400	560.858453	50.26036	6.44966E+15
Gilmer	878942080	318.033214	44.5842	3.10539E+15
Jackson	1220555904	252.196695	42.61932	3.26894E+15
Calhoun	725900992	307.80376	43.69557	2.43272E+15
Mason	1152245888	227.116475	41.11225	2.68082E+15
Pendleton	1807532672	794.104907	38.86252	1.38995E+16
Roane	1252050048	296.208663	43.66887	4.03547E+15

Table C1.1 continued.

County	Area m^2	Avg. elevation m.	30 y avg. rainfall in.	geopot. energy
Braxton	1337042688	376.932653	47.07839	5.91199E+15
Pocahontas	2437553408	989.455485	49.93845	3.00115E+16
Webster	1439527296	753.490796	52.94361	1.43092E+16
Putnam	906781952	251.909579	41.98552	2.38974E+15

Clay	889922560	372.487511	46.3062	3.82477E+15
Kanawha	2357247232	325.598119	44.10259	8.43439E+15
Cabell	745557888	639.549	42.71017	5.07445E+15
Nicholas	1693563264	639.549502	49.14842	1.32644E+16
Wayne	1326469120	272.992341	43.54009	3.92862E+15
Lincoln	1136250368	290.620653	44.14746	3.63253E+15
Greenbrier	2651428096	808.361377	45.13994	2.41073E+16
Fayette	1730641664	612.812798	45.63472	1.20596E+16
Boone	1302429440	428.168433	46.35194	6.4408E+15
Logan	1179267712	435.418879	46.64979	5.96859E+15
Raleigh	1576129536	704.715715	43.79303	1.21203E+16
Mingo	1097541376	403.322368	45.97489	5.07104E+15
Summers	951547136	672.4003	38.51943	6.14102E+15
Wyoming	1299047680	596.885295	45.0688	8.70752E+15
Monroe	1225340928	708.407376	38.52779	8.3333E+15
Mercer	1088748160	768.072665	37.73166	7.8621E+15
McDowell	1384392576	599.940657	42.65404	8.82735E+15
Total	6.2723E+10			3.655E+17

7 **Geopotential of runoff** 6.02 E+16 **J/y**

Geopotential energy of runoff (physical energy of streams) =
(area)(mean elevation – (base elevation when > sea level)(runoff)(density)(gravity)
The annual runoff is a 30 year average. The elevation was also an average based on known elevations in the selected area *(15)*.

Watershed		
(Great Cacapon, WV)	Area	1.75E+09 m^2
	Elevation	609.6 m
(Potomac, Harper's Ferry)	Base elev.	73.2 m
	Runoff/yr	0.3175 m/y
	Density	1000 kg/m^3
	Gravity	9.81 m/s^2
	Energy	2.93E+15 J/y
(Bemis, WV)	Area	2.98E+08 m^2
	Elevation	1987 m
(Cheat R., Morgantown)	Base elev.	250.5 m
	Runoff/yr	1.069 m/y
	Density	1000 kg/m^3

	Gravity	9.81	m/s^2
	Energy	5.420E+15	J/y
(Little, WV)			
	Area	1.09E+07	m^2
	Elevation	1215	m
(Ohio R., Parkersburg)	Base elev.	171.3	m
	Runoff/yr	0.48006	m/y
	Density	1000	kg/m^3
	Gravity	9.81	m/s^2
	Energy	5.358E+13	J/y
(Buckeye, WV)			
	Area	1.40E+09	m^2
	Elevation	2303	m
(Ohio R., Point Pleasants)	Base elev.	156.7	m
	Runoff/yr	0.5715	m/y
	Density	1000	kg/m^3
	Gravity	9.81	m/s^2
	Energy	1.683E+16	J/y
(Clay, WV)			
	Area	2.57E+09	m^2
	Elevation	1821	m
(Ohio R., Point Pleasants)	Base elev.	156.7	m
	Runoff/yr	0.68072	m/y
	Density	1000	kg/m^3
	Gravity	9.81	m/s^2
	Energy	2.855E+16	J/y
(Julian, WV)			
	Area	8.24E+08	m^2
	Elevation	1667	m
(Ohio R., Huntington)	Base elev.	149.1	m
	Runoff/yr	0.52578	m/y
	Density	1000	kg/m^3
	Gravity	9.81	m/s^2
	Energy	6.45E+15	J/y

8 **River Chemical Potential**

Absorbed	**2.90E+14 J/y**
Received	**9.06E+16 J/y**

River chemical potential energy received = (volume flow)(density)(Gibbs free energy relative to seawater)
River chemical potential energy absorbed = (volume flow)(density) (Gibbs free energy solutes at river entry – Gibbs free energy solutes at river egress)

The Ohio and New Rivers begin and end outside state boundaries delivering part of the chemical potential energy that they carry to the state.

Total Dissolved solids concentration from the USGS data *(16)*.
Gibbs Free energy, G = RT/w ln(C2/C1) = [(8.3143 J/mol/deg)(288 K)/(18 g/mol)] * ln [(1E6 - S)ppm)/965000]

Ohio River*	Vol. flow (Water Data - USGS)	2.948 E+10 m^3/yr
	Density	1000000 g/m^3
Solutes in (at Sewickley, PA)		211.96 ppm
	G. in	4.711 J/g
Solutes. out (Point Pleasant)		295.55
	G. out	4.700 J/g
	absorbed	3.279E+14 J/y
	received	1.389E+17 J/y

New River (Water Data - USGS)	Vol. flow	4.466 E+09 m^3/yr
	Density	1000000 g/m^3
Solutes in (Glen Lyn)		84 ppm
	G. in	4.728 J/g
Solutes out (Point Pleasant)		295.5
	G. out	4.700 J/g
	absorbed	1.257E+14 J/y
	received	2.112E+16 J/y

*If the river flows along the border the state, the energy was distributed equally between the states on opposite sides of the river.

9 **River Geopotential**

Absorbed	**2.06E+16 J/y**
Received	**4.99E+16 J/y**

Geopotential energy received (relative to sea level) = (flow vol.)(density)(height at entry)(gravity).
Geopotential energy absorbed = (flow vol.)(density)(height entry - height egress)(gravity)
Ohio and New Rivers are the only rivers that begin and end outside of the state
Data on water flow and height of the gauge are from USGS Water Resources Data *(17)*.

Ohio River*	Vol. Flow	2948 E+10 m^3/yr
	(Water data - USGS)	
	Density	1000 kg/m^3
	Height In	207.26 m
	(Height at Sewickley, PA)	
	Height Out	155.45 m
	(Height at Point Pleasant)	
	Gravity	9.81 m/s^2
	Absorbed	1.499E+16 J/y
	Received	5.994E+16 J/y

New River	Vol. Flow	4.466 E+9 m3/yr
(Water Data - USGS)		
	Density	1000 kg/m^3
	Height In	454.23 m
(at Glen Lyn, VA)		
	Height Out	155.45 m
(at Point Pleasant)		
	Gravity	9.81 m/s^2
	Absorbed	1.309E+16 J/y
	Received	1.99E+16 J/y

*If the river borders the state half the calculated energy was used

10 **Agricultural Products** **1.759E+16 J/y**

(amount sold)(energy/unit)

Production data is from the West Virginia Agricultural Statistics Service Tables 42,43, and 37 in *(18)*. Energy per unit value used was found in the USDA Nutrient Data Laboratory *(1)*.

Hay	Mass	8.0382E+11 g/y
	Energy/unit	18901 J/g
		1.519E+16 J/y
Oats		132,249 bushels/yr
		14514.96 g/bushels
	Mass	1,919,588,945 g/y
	Energy/unit	16280 J/g
		3.125E+13 J/y
Wheat		421,453 bushels/y
		27215.54 g/bushel
	Mass	11,470,070,980 g/yr
	Energy/unit	14230 J/g
		1.632E+14 J/y

Corn		3,651,139	bushels/y
		25401.17	g/bushels
	Mass	92,743,202,433	g/yr
	Energy/unit	19736	J/g
		1.830E+15	J/y
Tobacco	Mass	2737090	lbs/y
		1,241,522,948	g/y
	Energy/unit	14651	J/g
		1.819E+13	J/y
Soybeans		482,228	bushels/y
		27215.54	g/bushels
	Mass	13,124,095,423	g/y
	Energy/unit	17,410	J/g
		2.285E+14	J/y
Apples	Mass	52,394,370,290	g/y
	Energy/unit *(1)*	2160	J/g
		1.142E+14	J/y
Peaches	Mass	4,615,592,663	g/y
	Energy/unit *(1)*	1650	J/g
		7.616E+12	J/y
Wool	Mass	80,796,141	g/y
	Energy/unit	20934	J/g
		1.691E+12	J/y

11 **Livestock** **4.00E+15 J/y**

(annual production mass)(energy/mass)

The amount sold is taken from the 1997 Census of Agriculture *(18)*.

Turkeys	# sold	4468456	
	wt	7257.5	g/animal
	Energy /unit *(1)*	6690	J/g All classes, meat and skin
		2.170E+14	J/y
Cows	# sold	863647	
	wt	3.5E+05	g/animal
	Energy /unit *(1)*	12180	J/g Choice carcass
		3.7E+15	J/y
Hog/Pig	# sold	24884	
	wt	9.00E+04	g/animal

	Energy /unit *(1)*	15730 J/g	Fresh carcass
		3.52E+13 J/y	
Sheep/lamb	# sold	40709	
	wt	68038.9 g/animal	
	Energy /unit *(1)*	7406 J/g	Raw leg, shoulder, arm
		2.051E+13 J/y	
Horses	# sold	16787	
	wt	476271.99 g/animal	
	Energy /unit *(1)*	5560 J/g	
		4.445E+13 J/y	

12 **Fish Production** **7.22E+11 J/y**

(mass)(energy/mass)

Based on the 1998 trout sales of stocked fish reported by the US Department of Agriculture, 1998 Census of Aquaculture *(19)*.

Mass	369,000	lbs/y
	453.59	g/lb
Energy/mass	4311.58	J/g

13 **Hydroelectricity** **4.09E+15 J/y**

Energy Information Administration, Electricity Net Generation by Fuel in West Virginia, 1997 *(20)*.

14 **Net Timber Growth** **2.10E+17 J/y**

Based on forest growth from 1975 to 1989, from the last inventory done for West Virginia by the U.S. Forest Service *(21)* (DiGiovanni 1990).

Forest Growth	491,132,000	ft^3
	1.39E+13	cm^3
green wt	1	g/cm^3
Forest growth	1.39E+13	g/y

15 **Timber Harvest** **2.29E+16 J/y**

Based on the forest statistics for West Virginia *(21)* DiGiovanni (1990).

Forest Harvest	462,542,000	board ft
	84,098,545	ft^3
	2.38E+12	cm^3
dry wt	0.5	g/cm^3
Forest mass	1.19E+12	g/y

16 **Groundwater Chemical Potential Energy** **9.49E+14 J/y**

(vol.)(density)(Gibbs free energy)

Based on the volume of ground water withdrawn in 1995 *(22)*.

$G = RT/w \ln(C2/C1) = [(8.3143 \text{ J/mol/deg})(288 \text{ K})/(18 \text{ g/mol})] * \ln [(1E6 - S)\text{ppm})/965000]$

Volume used	2.02E+08 m^3/y
(US Geological Survey on water use for state)	
Density	1000000 g/m^3
S	342 ppm
Gibbs	4.69 J/g

C2 Notes for Table 5 – Annual Production and Use of Nonrenewable Resources in 1997.

17 **Coal Production** **4.64E+18 J/y**

Provided by the West Virginia Department of Energy *(23)*. Unit conversions may be found at (24).

Short tons/y	1.74E+08
g/short ton	9.07E+05
J/g	2.94E+04

18 **Coal Used in the State** **9.92E+17 J/y**

Provided by the West Virginia Department of Energy *(23)*.

Short tons/y	3.72E+07
g/short ton	9.07E+05
J/g	2.94E+04

19 **Natural Gas Production** **1.89E+17 J/y**

Taken from the Energy Information Administration Natural Gas Summary Statistics for Natural Gas - West Virginia, *(25)*. The annual flows of natural gas are not exactly balanced because gas is taken and removed from underground storage. The flows balance over a longer averaging period.

Amount	1.72E+08 1000 ft^3
J/1000 ft^3	1.1E+09

20 **Natural Gas Used in the State** **1.75E+17 J/y**

Taken from the Energy Information Administration Natural Gas Summary Statistics for Natural Gas - West Virginia *(25)*.

Amount	1.59E+08 1000 ft^3
J/1000 ft3	1.1E+09

21 **Petroleum Production** **9.2E+15 J/y**

From Utah's Department of Natural Resources - Energy Office *(26)*

22 **Petroleum Used in the State** **2.3E+17 J/y**

(Energy Information Administration) From the State Energy Data Report of West Virginia 1960-1999. *(27)*

23 **Electricity Production** (without hydroelectricity) **3.26E+17 J/y**

Energy Information Administration *(28)*.

Amount 90418730400 kW-hr

24 **Electricity Used in the State** **9.45E+16 J/y**

Energy Information Administration. From the State Energy Data Report of West Virginia 1960-1999. (27)

2.62E+10 kW hr

Mineral Production

Taken from the 1997 and 1998 Mineral Industry Studies of West Virginia by the US Geological Survey and the West Virginia Geological and Economic Survey *(29)*.

25 **Clay** 151000 tons **2.96E+20 sej/y**

Emergy/Mass 1961864407 sej/g

(From Odum 1996)

26 **Sand and gravel** 1670000 tons **3.34E+21 sej/y**

Emergy/Mass 1.31E+09 sej/g

(Calculated in this study)

27 **Limestone** 12000000 tons **1.18E+22 sej/y**

Emergy/Mass 980932203 sej/g

(From Odum 1996)

28 **Sandstone** 856 tons **8.40E+17 sej/y**

Emergy/Mass 980932203 sej/g

(From Odum 1996)

29 **Soil Erosion** Total **5.03E+15 J/y**

Agricultural lands **3.99E+15 J/y**

(farmed area)(erosion rate)(organic fraction)(energy)

The farmed area was taken from the 1997 census of Agriculture *(18)*.

The organic fraction was taken from Odum (1996).

Erosion rates for cropland and pasture from the USDA *(30)* and for forest from Patric et al. (1984).

Cultivated Crop	Area	641899.62 acres
	Erosion rate	4.3 ton/acre/yr
	Erosion	27601685 ton/yr
	Org. fraction	0.03
		907185 g/ton
		22604.4 J/g
	Energy	1.69803E+15 J/y
Non-Cultivated	Farmed area	695391.26 acres
	Erosion rate	0.8 ton/acre/yr
	Erosion	556313 ton/yr

	Org. fraction	0.03	
		907184.74	g/ton
		22604.4	J/g
	Energy	3.42239E+14	J/y
Pastureland	Area	528696.4	acres
	Erosion rate	6	ton/acre/yr
	Erosion	3172178	ton/yr
	Org. fraction	0.03	
		907184.74	g/ton
		22604.4	J/g
	Energy	1.9515E+15	J/y
Forested Land	Area	12173404.9	acres
	Erosion rate	0.139	ton/acre/yr
	Erosion	1692103	ton/yr
	Organic fraction	0.03	
		907184.74	g/ton
		22604.4	J/g
	Energy	1.04097E+15	J/y

The erosion rate for the forested land was measured at Shavers Fork, WV.

C3. Notes for Table 6 - Imports to the West Virginia economy in 1997.

30 **Coal** **2.32E+17 J/y**

Provided by the West Virginia Department of Energy *(23)*.

Short tons/yr	8.70E+06
g/short ton	9.07E+05
J/g	2.94E+04

31 **Petroleum** **2.2E+17 J/y**

Value is the difference between the production and consumption within the state. Also estimated from the data in the 1997 Commodity Flow Survey *(2)*.

32 **Natural Gas (Received at state border)** **2.0E+18 J/y**

Taken from the Energy Information Administration data on Natural Gas *(5)*.
Most natural gas received passes through the state and thus it is not considered as an import. This value would not usually be shown in an emergy analysis, but it is given here to a give an idea of the emergy flows linking the nation.
Summary Statistics for Natural Gas - West Virginia,

Amount	1.79E+09	1000 ft^3

J/1000 ft^3 1.1E+09

33 **Iron Ore** **4.41E+13 J/y**

Data from Weirton Steel. Iron ore to satisfy 1997 production.

3.00E+06 tons/yr
2.72E+12 g/yr
16.2 J/g

34 **Bauxite imported (corrected number)** **4.4E+13 J/y**

Assume the ratio of bauxite ore to primary aluminum production is 4:1, alumina to production is 2:1(Century Aluminum, Ravenswood WV).

Aluminum production 1.7E+05 m ton/yr
bauxite 6.7E+05 m ton/yr
6.7E+11 g/yr
6.5E+01 J/g

35 **Emergy of Services in Goods Imported** **2.99E+22 sej/y**

Data on shipments from the 1997 Commodity flow Survey, US. Census Bureau *(2)*.

		Units
Total in bound shipments	3.33E+10	$/y
Shipments of West Virginia origin	8.34E+09	$/y
Dollar value of imported goods	2.50E+10	$/y
Emergy to dollar ratio for the US in1997	1.20E+12	sej/$
Emergy in the services embodied in imported goods	2.99E+22	sej/y

36 **Emergy of Materials in Imported Goods (without fuels)** **9.48E+22 sej/y**

Data on material shipments into West Virginia by commodity class from the 1997 Commodity Flow Survey *(2)*, Additional State Data, Table 12. See Appendix B for the calculation of average transformities for the SCTG commodity classes. Appendix D gives details of the method of calculation used here.

Table C3.1 Emergy imported to West Virginia in material commodity flows.

SCTG Code	Commodity Class	J or g y^{-1}	Emergy per unit	Units	Emergy sej y^{-1}
1	Live animals and live fish.	9.42E+13	4.39E+05	sej/J	4.14E+19
2	Cereal grains.	1.10E+15	1.82E+05	sej/J	1.99E+20
3	Other agricultural product.	2.09E+15	2.33E+05	sej/J	4.88E+20
4	Animal feed and products of animal origin.	4.58E+15	1.22E+06	sej/J	5.58E+21
5	Meat, fish, seafood, and their preparations.	1.91E+15	3.27E+06	sej/J	6.24E+21
6	Milled grain products and preparations.	2.93E+15	1.82E+05	sej/J	5.33E+20
7	Other prepared foodstuffs and fats and oils.	1.80E+16	1.12E+06	sej/J	2.01E+22
8	Alcoholic beverages.	3.62E+14	5.89E+04	sej/J	2.13E+19
9	Tobacco products.	6.05E+14	6.50E+05	sej/J	3.93E+20
10	Monumental or building stone.	3.23E+09	9.81E+08	sej/g	3.17E+18
11	Natural sands.	3.69E+11	1.96E+09	sej/g	7.23E+20
12	Gravel and crushed stone.	6.46E+12	4.91E+08	sej/g	3.17E+21
13	Nonmetallic minerals.	7.30E+11	1.96E+09	sej/g	1.43E+21

14	Metallic ores and concentrates.	3.04E+10	2.71E+09	sej/g	8.23E+19
15	Coal	2.25E+17	3.92E+04	sej/J	8.84E+21
17	Gasoline and aviation turbine fuel.	1.07E+17	6.47E+04	sej/J	6.93E+21
18	Fuel oils.	7.04E+16	6.47E+04	sej/J	4.56E+21
19	Coal and petroleum products.	5.22E+16	6.47E+04	sej/J	3.38E+21
20	Basic chemicals.	2.06E+12	2.75E+09	sej/g	5.65E+21
21	Pharmaceutical products.	3.55E+10	2.75E+09	sej/g	9.77E+19
22	Fertilizers	1.94E+11	2.99E+09	sej/g	5.80E+20
23	Chemical products and preparations.	1.89E+11	9.90E+09	sej/g	1.87E+21
24	Plastics and rubber.	4.61E+11	2.71E+09	sej/g	1.25E+21
25	Logs and other wood in the rough.	3.24E+15	1.96E+04	sej/J	6.35E+19
26	Wood products.	5.67E+11	1.49E+09	sej/g	8.44E+20
27	Pulp, newsprint, paper, and paperboard.	6.01E+15	1.40E+05	sej/J	8.40E+20
28	Paper or paperboard articles.	3.18E+15	1.67E+05	sej/J	5.33E+20
29	Printed products.	6.58E+10	4.95E+09	sej/g	3.26E+20
30	Textiles, leather, and articles.	1.74E+15	7.18E+06	sej/J	1.25E+22
31	Nonmetallic mineral products.	2.46E+12	3.09E+09	sej/g	7.60E+21
32	Base metal in primary or semi-finished form	1.30E+12	5.91E+09	sej/g	7.70E+21
33	Articles of base metal.	4.42E+11	5.91E+09	sej/g	2.61E+21
34	Machinery	1.15E+11	7.76E+09	sej/g	8.89E+20
35	Electronic and other electrical equipment	1.57E+11	7.76E+09	sej/g	1.22E+21
36	Motorized and other vehicles.	6.82E+11	7.76E+09	sej/g	5.29E+21
37	Transportation equipment.	3.83E+10	7.76E+09	sej/g	2.97E+20
38	Precision instruments and apparatus.	4.61E+09	7.76E+09	sej/g	3.58E+19
39	Furniture, mattresses, lamps, lighting	4.81E+10	2.89E+09	sej/g	1.39E+20
40	Miscellaneous manufactured products.	2.66E+11	1.61E+09	sej/g	4.29E+20
41	Waste and scrap.	6.24E+11	2.16E+09	sej/g	1.35E+21
43	Mixed freight.	5.85E+11	6.32E+09	sej/g	3.70E+21
0	Commodity unknown.	8.01E+10	?		?
	Total			sej/y	1.19E+23
	Total without fuels			sej/y	9.48E+22

37 Services

The emergy in imported and exported services was determined using a variation of the base-nonbase method from economic analysis. Data on employment and revenues by NAICS sector for West Virginia and for the United States as whole (31) were used to estimate services exported and imported from the state using a modification of the location quotient and assumption methods. The formulae in the text are evaluated using data from the tables below.

Table C3.2 Export and Import of Services Between West Virginia and the Nation

	Economic Sectors								
Parameters	Agricult..	Mining	Utilities	Construct.	Manufact.	Wholesale	Retail trade	Transport.	Informat.
US sector (N_i)	0.0249	0.0041	0.0057	0.0457	0.1362	0.0467	0.1128	0.0236	0.0247
State Sector (S_i)	0.0337	0.0349	0.0113	0.0457	0.1062	0.0347	0.1314	0.0212	0.0173
(S_i - N_i)	0.0089	0.0308	0.0057	0.0000	-0.0300	-0.0120	0.0186	-0.0024	-0.0074
$/employee US	70034	341821	585899	151563	227502	700357	175889	108959	203255
$/emp. WV	19321	264699	420160	99198	251237	432277	156048	136256	149509

Location Quotient	1.36	8.50	2.00	1.00	0.78	0.74	1.16	0.90	0.70
$(S_i) \div (N_i)$	0.007	0.047	0.011	0.006	0.004	0.004	0.006	0.005	0.004
$(S_t) \div (N_t)$	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
Basic jobs (B)	6075.20	21113.14	3882.36	-4.04	-20546.35	-8239.19	12742.19	-1620.47	-5088.21
Exp(+) or imp(-) $*	1.17E+08	5.59E+09	1.63E+09	-6.12E+05	-4.67E+09	-5.77E+09	1.99E+09	-1.77E+08	-1.03E+09
Services in Sector	none	part	part	imports	none	Local (no)	Local (no)	Local (no)	imports
Assumption	Base	Base	Base	nonbase	Base	nonbase	nonbase	nonbase	nonbase
$ value of goods	all goods	5.03E+09	1.38E+09		all goods				
Services exported#	0	5.61E+08	2.48E+08		0				

*Export is determine by multiplying basic jobs by the $/employee in the West Virginia sector. Potential import is determined by multiplying the basic job deficit by the $ per employee in the U.S. sector. Basic sectors can export.

The export sectors summed here are only part service at this level of sector aggregation. Subtracting the dollar value of the goods exported in the sector from total estimated exports gives an estimate of the services exported. An alternative method (Table C3.2) considers higher resolution sector data where the export sectors evaluated are all service.

Economic Sectors continued:

	Finance& Insurance	RealEstate & Rental	Profession. Scientific	Managem.	Administ. Support	Education Services	HealthCare Social Ser.	Arts& Entertain.	Accomo. & Food
US sector (N_i)	0.0471	0.0137	0.0432	0.0211	0.0593	0.0026	0.1094	0.0128	0.0762
State Sector (S_i)	0.0308	0.0085	0.0240	0.0069	0.0313	0.0012	0.1397	0.0096	0.0752
$(S_i - N_i)$	-0.0162	-0.0053	-0.0192	-0.0142	-0.0280	-0.0014	0.0303	-0.0032	-0.0010
$/employee US	376639	141515	111029	35328	40278	63659	65262	65956	37074
$/employee WV	205448	114420	75120	30082	37138	45921	60844	49389	31694
Location Quot.	0.66	0.62	0.56	0.33	0.53	0.47	1.28	0.75	0.99
$(S_i) \div (N_i)$	0.004	0.003	0.003	0.002	0.003	0.003	0.007	0.004	0.005
$(S_t) \div (N_t)$	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
Basic jobs (B)	-11113.89	-3599.22	-13175.53	-9750.06	-19172.28	-931.94	20767.66	-2205.81	-718.72
Exp(+) imp(-) $*	-4.19E+09	-5.09E+08	-1.46E+09	-3.44E+08	-7.72E+08	-5.93E+07	1.26E+09	-1.45E+08	-2.66E+07
Services in Sector	Imports	Local (no)	Imports	Imports	Imports	Imports	Local (no)	Imports	Imports
Assumptions	nonbase	nonbase	nonbase	non base	nonbase	nonbase	nonbase	nonbase	Base

Sectors continued:

	Other Ser.	Auxillar.	Governm.
US sector (N_i)	0.0263	0.0064	0.1576
State Sector (S_i)	0.0264	0.0071	0.2028
$(S_i - N_i)$	0.0002	0.0007	0.0452
$/employee US	81659	14231	141198
$/employee WV	64655	1279	51394
Location Quot.	1.01	1.11	1.29
$(S_i) \div (N_i)$	0.006	0.006	0.007
$(S_t) \div (N_t)$	0.006	0.006	0.006
Basic jobs (B)	112.39	492.67	30980.10
Exp(+) imp(-) $*	7.27E+06	6.30E+05	1.59E+09
Services in Sector	Local (no)	Local (no)	Local (no)
Assumptions	nonbase	nonbase	Base

Table C3.3 Alternative Method for Determining Exports: Detailed Analysis of the Mining and Utilities sectors

	Drilling oil & gas wells	Support activities for oil & gas	Support activities for coal	Electric services
US sector (N_i)	0.0004	0.0009	0.0000	0.0020
State Sector (S_i)	0.0007	0.0014	0.0021	0.0032
(S_i - N_i)	0.0003	0.0006	0.0021	0.0012
$/employee US	138072	5451	22610483	465837
$/employee WV	77043	77270	135639	398779
Location Quot.	1.7317	1.6791	52.6411	1.6347
(S_i) ÷ (N_i)	0.0096	0.0093	0.2910	0.0090
(S_t) ÷ (N_t)	0.0055	0.0055	0.0055	0.0055
Basic jobs (B)	214	398	1425	850
Exp(+) imp(-) $*	1.65E+07	3.08E+07	1.93E+08	3.39E+08
Service exported ($)	5.80E+08			

Table C3.4 Determination of Imported and Exported Services

Potential for Importing ($)	8.01E+09	Multiply deficit employment times U.S. worker productivity in sectors assumed to be capable of importing services in Table C3.1 and sum over the sectors.
Fraction of potential ($) imported	6.17E+09	We assume that states with average per capita income can import the services deficit and that states below US avg. per capita income can import a fraction of the deficit equal to average per capita income of the state /average U.S. per capita income. In 1997 this fraction was $19628/$25412 or 0.77 for West Virginia. Multiply potential imports by 0.77 to estimate imported services.
Emergy in exported services sej/y	7.0E+20	Multiply the basic employment in the detailed service sectors above by West Virginia worker productivity and sum. Multiply this dollar amount by the emergy to dollar ratio of the U.S. in 1997 to estimate the emergy exported
Emergy in imported services sej/y	7.4E+21	Product the imported services times the emergy to dollar ratio of the U.S. in 1997.

Table C3.5 West Virginia employment by sector and the dollars generated per employee, 1997.

Sectors NAICS	Number of Employees	Sales, Revenues, Shipments 1000 $	Dollars per Employee	Percent of total Employees
Agriculture	23135	447000	19321.37454	0.033749876
Mining	23927	6333463	264699.4191	0.034905264
Utilities	7767	3263383	420160.036	0.01133068
Construction	31312	3106093	99198.16684	0.045678674
Manufacturing	72813	18293309	251236.8533	0.106221298
Wholesale trade	23805	10290356	432277.0846	0.034727288
Retail trade	90087	14057933	156048.4088	0.131421011
Transportation	14526	1979257	136256.1614	0.021190867
Information	11862	1773480	149509.3576	0.017304561
Finance & Insurance	21144	4344000	205448.3541	0.030845359
Real Estate & rental	5812	665011	114420.3372	0.008478681
Professional Scientific	16462	1236618	75119.54805	0.024015148
Management	4720	141988	30082.20339	0.006885646

Administrative support	21445	796429	37138.21404	0.031284465
Education services	843	38711	45920.52195	0.001229788
Health care & social services	95738	5825082	60843.99089	0.139664821
Arts& entertainment	6571	324534	49388.82971	0.009585928
Accommodation & food	51529	1633164	31694.07518	0.075171703
Other services	18113	1171099	64655.1648	0.026423666
Auxiliaries	4873	6235	1279.499282	0.007108846
Government	139000	7143800	51394.2446	0.202776432

Table C3.6 US employment and productivity by Industry sector, 1997

Sectors NAICS	Employees	Sales, receipts or shipments $1000s	Dollars per Employee	Fraction of total Employees
Agriculture	3085992	216125000	70034.20618	0.024887236
Mining	509006	173988778	341820.6819	0.004104921
Utilities	702703	411713327	585899.4867	0.005667006
Construction	5664840	858581046	151563.1591	0.045684568
Manufacturing	16888016	3842061405	227502.2362	0.136194793
Wholesale trade	5796557	4059657778	700356.7425	0.04674681
Retail trade	13991103	2460886012	175889.35	0.1128324
Transportation	2920777	318245044	108959.0352	0.023554846
Information	3066167	623213854	203255.0262	0.024727356
Finance & Insurance	5835214	2197771283	376639.3628	0.047058563
Real Estate & rental	1702420	240917556	141514.759	0.013729306
Professional Scientific	5361210	595250649	111029.1611	0.043235919
Management	2617527	92473059	35328.40693	0.021109262
Administrative support	7347366	295936350	40277.88326	0.059253437
Education services	321073	20439028	63658.50757	0.00258932
Health care & social services	13561579	885054001	65261.86965	0.109368469
Arts& entertainment	1587660	104715028	65955.57487	0.012803815
Accommodation & food	9451226	350399194	37074.46992	0.076220189
Other services	3256178	265897685	81659.44399	0.026259715
Auxiliaries	792370	11275968	14230.68516	0.006390133
Government	19540000	2759000000	141197.5435	0.157581936

Table C3.7 West Virginia detailed export sector employment and the dollars generated per employee.

Sectors NAICS	Number of Employees	Sales, Revenues, Shipments 1000 $	Dollars per Employee	Percent of total WV Employees
Mining Services	2944	312178	106038.7228	0.004294776
Drilling oil&gas wells	506	38984	77043.47826	0.000738165
Support activities	985	76111	77270.05076	0.001436941

for oil & gas				
Support activities for coal	1453	197083	135638.6786	0.00211967
Electric services (electric power distribution))	2190	873325	398778.5388	0.003194823

Table C3.8 U.S. employment in detailed export sectors and the dollars generated per employee, 1997.

Sectors NAICS	Employees	Sales, receipts or shipments $1000s	Dollars per Employee	Fraction of total US Employees
Mining Services	168806	19898686	117879.0209	0.00136135
Drilling oil&gas wells	52858	7298223	138072.2502	0.000426278
Support activities for oil & gas	106118	11501280	5450.997946	0.000855797
Support activities for coal	4993	578449	22610483.28	4.02665E-05
Electric services (electric power distribution))	242347	112894143	465836.7671	0.001954427

38 **Federal Government**

Personal Income Tax	2631000000 **$/y**	Data Source: *(33)*
Social Security Tax	2150000000 **$/y**	State of West Virginia (1999)
Business Taxes	2067026316 **$/y**	State of West Virginia (1999)
Total Tax (effective export)	**6.85E+09 $/y**	
Total Outlay to government and individuals	**1.04E+10 $/y**	From the U.S. Statistical Abstract for 1998 *(33)*
Net Gov. Funds spent in WV $(1.04_{E+1}0)$-(6.85E9)	**3.56E+09 $/y**	

C4. Notes for Table 7 - Exports from the West Virginia Economy in 1997.

39 **Coal** **3.82E+18 J/y**

Provided by the West Virginia Department of Energy *(23)*.

Short tons/yr	1.43E+08
g/short ton	9.07E+05
J/g	2.94E+04

40 **Natural Gas (Production Exports)** **6.65E+15 J/y**

Calculated from the Energy Information Administration Natural Gas Summary Statistics for Natural Gas - West Virginia *(25)*, Export is production – consumption.

Amount	6.05E+06 1000 ft^3
J/1000 ft3	1.1E+09

41 **Natural Gas (Delivered at state border)** **2.08E+18 J/y**

Taken from the Energy Information Administration Natural Gas *(5)*. See Note 32 on the natural gas received at the state border.
Summary Statistics for Natural Gas - West Virginia *(25)*.

Amount	1.89E+09 1000 ft^3
J/1000 ft3	1.1E+09

42 **Electricity** **2.35E+17 J/y**

Energy Information Administration, *(28)*.
From the State Energy Data Report of West Virginia 1960-1999 *(27)*.
(Net generation)-(Consumption)
6.53E+10 kW h

43 **Steel** **2.00E+12 g/y**

From Greg Warren at Weirton Steel in Wheeling, West Virginia
2.20E+06 ton/y

44 **Services embodied in exported goods.**

Data on shipments from the 1997 Commodity Flow Survey *(2)*.
Data on electricity from EIA *(27)*. Electricity is not included in the CFS data.

		Units
Total shipments to all destinations	3.56E+10	$/y
Shipments to West Virginia destinations	8.34E+9	$/y
Dollar value of exported goods *(2)*	**2.72E+10**	$/y
Emergy to dollar ration for the US in 1997	1.20E+12	sej/$
Emergy exported in the services embodied in goods including fuels.	**3.27E+22**	sej/y
Dollars paid for electricity @ .05 $/KWh *(27)*	3.27E+09	$
Emergy in services in Electricity exported	3.92E+21	sej/y
Total Emergy in services embodied in goods.	**3.66E+22**	sej/y
Dollars paid for coal	3.92E+09	$
Emergy in services in coal exported	4.70E+21	sej/y

45 **Material in exported goods**

Data on material shipments from West Virginia to all states by commodity is from The U.S. Census Bureau's 1997 Commodity Flow Survey *(2)*, Additional State Data, Table 12. In cases below shipment weight from the commodity flow survey was converted to energy.
See Appendix B for the calculation of average emergy per unit for the commodity classes and a table giving the mass to energy conversions for the commodity class.

Table C4.1 Emergy in the materials exported from West Virginia

SCTG Code	Commodity Class	J or g	Emergy per unit	Units	Emergy sej y^{-1}
1	Live animals and live fish.	0	4.393E+05	sej/J	0
2	Cereal grains.	0	1.818E+05	sej/J	0
3	Other agricultural product.	0	2.334E+05	sej/J	0
4	Animal feed and products of animal origin.	4.034E+14	1.217E+06	sej/J	4.471E+20
5	Meat, fish, seafood, and their preparations.	1.720E+15	3.270E+06	sej/J	5.624E+21
6	Milled grain products and preparations.	2.857E+13	1.818E+05	sej/J	5.195E+18

7	Other prepared foodstuffs and fats and oils.	0	1.120E+06	sej/J	0
8	Alcoholic beverages.	0	5.886E+04	sej/J	0

Table C4.1 continued

SCTG Code	Commodity Class	J or g	Emergy per unit	Units	Emergy sej y^{-1}
9	Tobacco products.	1.595E+14	6.500E+05	sej/J	1.037E+20
10	Monumental or building stone.	0	9.810E+08	sej/g	0
11	Natural sands.	4.046E+11	1.962E+09	sej/g	3.969E+20
12	Gravel and crushed stone.	1.660E+11	4.905E+08	sej/g	8.143E+19
13	Nonmetallic minerals.	0	1.962E+09	sej/g	0
14	Metallic ores and concentrates.	0	2.711E+09	sej/g	0
15	Coal	3.82E+18	3.924E+04	sej/J	1.500E+23
17	Gasoline and aviation turbine fuel.	0	6.475E+04	sej/J	0
18	Fuel oils.	4.021E+14	6.475E+04	sej/J	2.604E+19
19	Coal and petroleum products.	1.26E+17	6.475E+04	sej/J	8.170E+21
20	Basic chemicals.	3.860E+12	2.750E+09	sej/g	1.061E+22
21	Pharmaceutical products.	0	2.750E+09	sej/g	0
22	Fertilizers	0	2.993E+09	sej/g	0
23	Chemical products and preparations.	5.951E+11	9.902E+09	sej/g	5.893E+21
24	Plastics and rubber.	8.428E+11	2.709E+09	sej/g	2.283E+21
25	Logs and other wood in the rough.	2.9667E+16	1.962E+04	sej/J	5.821E+20
26	Wood products.	2.562E+12	1.490E+09	sej/g	3.816E+21
27	Pulp, newsprint, paper, and paperboard.		1.398E+05	sej/J	0
28	Paper or paperboard articles.	5.752E+14	1.674E+05	sej/J	9.631E+19
29	Printed products.	0	4.951E+09	sej/g	0
30	Textiles, leather, and articles.	0	7.177E+06	sej/J	0
31	Nonmetallic mineral products.	1.224E+12	3.094E+09	sej/g	3.787E+21
32	Base metal in primary or semi-finished form	4.802E+12	5.906E+09	sej/g	2.836E+22
33	Articles of base metal.	3.502E+11	5.906E+09	sej/g	2.068E+21
34	Machinery	1.261E+11	7.755E+09	sej/g	9.779E+20
35	Electronic and other electrical equipment	8.375E+10	7.755E+09	sej/g	6.495E+20
36	Motorized and other vehicles.	4.107E+11	7.755E+09	sej/g	3.185E+21
37	Transportation equipment.	0	7.755E+09	sej/g	0
38	Precision instruments and apparatus.	0	7.755E+09	sej/g	0
39	Furniture, mattresses, lamps, lighting	2.994E+10	2.890E+09	sej/g	8.652E+19
40	Miscellaneous manufactured products.	9126E+10	1.613E+09	sej/g	1.472E+20
41	Waste and scrap.	0	2.161E+09	sej/g	0
43	Mixed freight.	1.007E+11	6.316E+09	sej/g	2.064E+20
0	Commodity unknown.	0	?	?	
	Natural Gas (joules)		4.80E+04	sej/J	3.19E+20
	Total				2.279E+23
	Total without fuels (15,17,18, natural gas)				**7.76E+22**
	Exported fuels				1.503E+23

46 **Services** See calculations at Note 37 above.
Dollar value of services exported **5.796E+08** $/y

Emergy in exported services 6.96E+20 sej/y

47 **People**

1997 Net Migration -9863 Individuals

Using the age percentages from the 1990 Census data

Number of individuals

	1990		1997
Preschool	21680	1.33%	-131
School	1166871	71.50%	-7052
College	385026	23.59%	-2327
Grad			
Post-College	56382	3.45%	-341
Total	1629959	99.8780599%	

The emergy per unit is expressed as sej/ind so the numbers are not put in energy terms.

48 **Tourism,** Estimate provided by the West Virginia Department of Transportation *(32)*. **4.00E+09 $**

C5. Notes for Table 8 - Value of West Virginia Storages in 1997.

49 **Forest Storage** **1.04E+19 J**

Based on the forest statistics for West Virginia in the last inventory done by the U.S. Forest Service in 1989 Digiovanni (1990).

Forest Standing mass	7.60E+08	tons
	6.89E+14	g
	15069.6	J/g

50 **Available Coal Reserves** **1.42E+21 J**

Based on the estimated recoverable coal reserves in 1998 by the West Virginia Bureau of Commerce *(34)*.

mass	53326657317	tons
g/short ton	9.07E+05	
J/g	2.94E+04	J/ton

51 **Available Petroleum Reserves** **1.19E+17 J**

Taken from *(35)* the Energy Information Administration Department of Energy.

Amount	2.10E+07	Barrels
	5.4E+06	Btu/barrel
	1.1E+14	Btu/yr

52 **Available Natural Gas Reserves** **3.13E+18 J**

Taken from *(5)* the Energy Information Administration Department of Energy (1997).

Amount	2.85E+09	1000 ft^3
J/1000 ft3	1.1E+09	

53 **People**

Using the percentages from the 1990 Census data

1997 Population	1816000	people

Number of individuals

	1990	Fraction 1990	1997
Preschool	21680	0.0121	21952
School	1166871	0.6506	1181525
College Grad	379048	0.2113	383808
Post-College	50403	0.0281	51036
Elderly (65+)	157540	0.0878	159518
Public Status*	17935	0.0100	18160
Legacy#	792		792

*Public Status is estimated as one per cent of total population.

#All individuals listed in the index to *West Virginia: A History* by O.K. Rice are counted as part of West Virginia's legacy.

A few of those legacy individuals are:

Henry Davis - West Virginian senator and democratic candidate for the Vice Presidency of the United States in 1904 (lost to Roosevelt and Fairbanks)

Belle Boyd - confederate spy born in Martinsburg, WV

John Brown - known for his actions at Harper's Ferry

Pearl S. Buck - author who won the Nobel prize for literature in 1938, born in Hillsboro

Alexander Campbell, religious leader and educator. Bethany College and the Disciples of Christ.

Cornstalk - Shawnee Indian chief

John Davis - constitutional lawyer who argued 140 cases in the Supreme Court, most at the time also the unsuccessful democratic candidate for the US Presidency in 1924 (lost to Coolidge), born in Clarksburg.

Thomas J. "Stonewall" Jackson - confederate general, and exemplary leader.

John Kenna - West Virginian representative and senator, born in St. Albans.

Walter Reuther - president of the United Automobile Workers, born in Wheeling.

Francis Pierpont - governor of the "Restored Government of Virginia" during the Civil War born in Morgantown

Mary Harris "Mother" Jones - leader of strikers in the coal camps who fought for fair labor laws

C6. Notes for Table 9– Summary Flows for West Virginia in 1997

54 Renewable emergy sources received (Table 4) are the chemical potential energy in rain, the energy of the earth cycle, and the chemical potential energy in rivers. Renewable emergy sources absorbed by (used in) the system are the chemical potential energy of rain evapo-transpired, the geopotential of runoff doing work on the land, and the chemical potential and geopotential energy of the rivers used as the river flows through the state.

55 Nonrenewable sources (Table 5) include fuels and minerals coal, natural gas, petroleum, clay, sand and gravel, limestone and soil erosion where it exceeds soil building, *i.e.*, in agricultural areas.

56 Dispersed Rural Source (Table 5) is the soil erosion in agricultural areas. This category includes any renewable resource that is being used more rapidly then it is being replaced.

57 Mineral Production (Table 5) is the emergy in the mined tonnage of coal, natural gas, petroleum, clay, limestone, sandstone, sand and gravel.

58 Fuels exported without use are the quantities of coal and natural gas exported without first being used in a production process in the state. (coal production + import – use = 1522 E+20 sej/y) compared to the commodity flow survey number for coal (1497 E+20 sej/y). Use commodity flow survey number and add 3 E+20 sej/y natural gas exports.

59 Imported minerals and fuels are coal, petroleum, iron ore and bauxite (Table 6).

60 Minerals used (includes fuels): Add mineral production and mineral imports and subtract fuels exported without use.

61 In state minerals used: Subtract minerals exported without use from mineral production.

62 The material imported in goods was determined from the 1997 Commodity Flow Survey by summing the tonnage by commodity class from states with significant exports to West Virginia. (see note 36).

63 Dollars paid for imports is the sum of the dollar value of imported goods including fuels and minerals and all other goods and services.

64 The services in imported minerals including fuels are determined below.

Table C6.1 Services in Imported Minerals

	Amount	$/amount	$
Iron Ore (T)	3.0E+06	28.9	1.73E+08
Bauxite (T)	6.7E+05	27	1.8E+07
Coal (sT)	8.704E+06	26.64	2.32E+08
Petroleum (Btu)	2.09E+14		
Petroleum (Barrels)	3.89E+07		
Petroleum (Gal)	1.63E+09	0.799	1.31E+09
		Total	1.73E+09

The prices of these items can be found in the data sources given at *(36)*

65 Dollars paid for goods without fuels and minerals is the total dollar value of goods imported from the CFS ($2.5_{E+1}0$) minus the dollar value in fuels and minerals calculated above.

66 Dollars paid for imported services as determined using the base-nonbase method (Table C3.3).

67 Federal transfer payments are the total outlay of funds by the Federal government (note 38).

68 Imported Services Total is the sum of the emergy in services associated with imported goods, fuels, and minerals, and pure services.

69 Imported Services in fuels and minerals is the emergy equivalent of the human service represented by the money paid for fuels and minerals. Dollars are convert to emergy using the 1997 emergy/$ ratio for the US.

70 Imported Services in Goods is the emergy equivalent of the money paid for goods minus that paid for fuels and minerals. (use 1.2E+12 sej/$).

71 Imported Service is the emergy equivalent of the money paid for services (note 37).

72 Emergy purchased by Federal dollars spent in the state. Use West Virginia emergy/$ ratio.

73 Exported Products is the emergy in the goods exported including electricity (Table 7).

74 Dollars Received for Exports is the sum of the payments for all exported goods and services

75 Dollars Received for Exported Goods other than fuels, is the dollar value of the exported goods ($2.72E+10) less fuels.

76 Dollars Received for fuels and electricity are determined in Table C6.2.

Table C6.2 Services in Exported Fuels and Electricity

		1997 prices	
	Amount	$/amount	$
Coal (Short T)	1.43E+08	26.64	3.8E+09
Natural Gas (tcf)	6.09E+06	3.00	1.8E+07

		Total fuels	3.92E+09
Electricity (kWh)	6.53E+10	0.05 $/kWh	3.27E+09

77 Dollars Paid for Services as determined by the base-non-base method given in (Note 37).

78 Dollars spent by tourists in West Virginia from West Virginia Dept. Transportation *(32)*.

79 Federal Taxes Paid is the sum of personal income, social security, and business taxes (Note 38).

80 Total Exported Services is the sum of the emergy equivalents in human service in fuels, goods and services exported.

81 Exported Services in Fuels is the emergy equivalent of the human service in the dollars paid for fuels exported. Service is determined using the US emergy/$ ratio.

82 Exported Services in Goods is the emergy equivalent of the services embodied in all value added exported goods (goods and electricity minus fuels exported without use).

83 Exported service is the emergy equivalent of the dollar value of exported services (Note 37)**.**

84 Emergy Purchased by Tourists is the emergy purchased when tourists $ are spent in West Virginia, *i.e*., at West Virginia's emergy to dollar ratio.

85 Emergy Purchases Forgone is the emergy equivalent of taxes paid to the Federal government. This number was determined using the West Virginia Emergy/$ ratio.

86 Gross State Product of the State of West Virginia in 1997.

C7. Notes for Table 10: Calculation of Emergy Indices.

87 Renewable Emergy received (note 54).

88 Renewable Emergy Absorbed (note 54).

89 In-State Nonrenewable Use is the sum of dispersed rural sources (N_0) and in-state mineral production (N_1).

90 Imported Emergy is the sum of imported minerals (F), goods (G), and services (PI).

91 Total Emergy Inflow is the sum of renewable emergy received (R_r), and the emergy imported in the previous note.

92 The total emergy used in the state (U) is the sum of the renewable emergy absorbed (R_a), the emergy used form dispersed rural sources (N_0), fuels and minerals used (F_1), and the goods (G) and services (PI) imported.

93 Total exported emergy is the sum of the emergy in the materials of exported goods (B), the emergy of services associated with goods and with pure service (PE) and the emergy of fuels and minerals exported without use (N_2).

94 The emergy used from home sources is the sum of emergy from dispersed rural sources, in-state minerals and fuels used (F_2), and renewable emergy absorbed divided by total use (U).

95 Import minus export is the difference between imported emergy (note 90) and exported emergy (note 93).

96 Ratio of exports to imports is the quotient of the expression in note 93 divided by the expression in note 91.

97 Fraction of use that is locally renewable is the ration of renewable emergy absorbed to total use.

98 Fraction of use that is purchased is the ratio of imported emergy (note 90) to total use (note 92).

99 Fraction of use in imported service is PI divided by U.

100 Fraction of use that is free is the sum of the renewable emergy absorbed and emergy from dispersed rural sources divided by total use.

101 Ratio of purchased to free is the quotient of the sum of imported fuels and minerals (F_1), imported goods (G) and imported services (PI) divided by the sum of the renewable emergy received (R_r) and the emergy from dispersed rural sources (N_0).

102 Environmental loading ratio is the quotient of the sum of the emergy from dispersed rural sources (N_0), imported fuels and minerals (F_1), imported goods (G) and imported services (PI) divided by the renewable emergy received (R_r).

103 Investment Ratio. There are several possible investment ratios (Odum 1996). This one compares imported emergy (note 90) to the emergy supplied form within the state. The emergy from within the state is the sum of the renewable emergy received (R_r), the emergy from dispersed rural sources (N_0), and the emergy from in-state fuels and minerals (F_2).

104 Emergy use per unit area (Empower density) is the total emergy use (U) divided by the area.

105 Use per person id the total emergy U divided by the population.

106 Renewable carrying capacity at the present standard of living is found by dividing the renewable emergy received by total use and then multiplying this fraction time the present population.

107 Developed carrying capacity at the present standard of living is approximately eight times the renewable carrying capacity.

108 West Virginia State Economic product (note 86).

109 Ratio of West Virginia emergy use to GSP. Divide U by X.

110 Ratio of U.S. Emergy use to GNP. See Appendix B3.2.

111 Ratio of emergy in electricity use to total use (El/U). See Table 5 for electricity use.

112 Ratio of electricity production to total use (Elp/U).). See Table 5 for electricity production.

113 Fuel use per person is the sum of coal, natural gas, and petroleum used in the state (Table 5, 620E+20 sej/y) divided by population.

114 Population of the State in 1997

115 Area of the State

Appendix D.

Calculating Imports and Exports of Materials and Services

D1. Creating Export/Import Spreadsheets for Materials

The method used to determine the emergy exported from and imported to West Virginia was further developed in this study to take advantage of the extensive data on this subject provided by the U.S. Census Bureau's Commodity Flow Survey *(2)*, which is performed every five years. This innovation resulted in a marked improvement in the accuracy with which imports and to a lesser extent exports to a state's economy can be determined. Even though the CFS provides all the information needed to document exports and imports it is not tabulated in the form that we need and some of the information is hidden rather deeply in the data base. To make our method transparent and reproducible, we have described in detail the characteristics of the database, data sources and methods that we used to determine the emergy imported and exported from West Virginia. These methods should be applicable to the determination of imports and exports for any other state. To facilitate following the method described below the appropriate tables from the CFS should be accessed when needed. If the data tables or presentation of information change in the future these instructions will have to be altered.

Export Calculations

Determining material and energy flows for exports is straightforward with few extrapolations or assumptions needed, because the data are relatively complete as provided in the CFS. Data on dollar value and tonnage of export shipments between states by commodity class comes from the Commodity Flow Survey (CFS), Table 12 (Additional State Data). This data is also summarized in Tables 5, 7, and 8 in the CFS. The CFS uses several data codes when a numeric measurement is not given and these codes were handled in a consistent manner. For example, most states have an S or a D in one or more data fields for some commodity shipments. These letters indicate variable data (S) or a single source of information (D) that would risk disclosure. In the export calculation method, no estimate of exports was made for commodity classes with and S or D in both the $ value and tonnage columns for instate shipments. When this occurs there is often an S or a D in the "all destinations" category, as well. In this case there are too many unknowns to make an estimate. Materials moving in these classes were assumed to remain within the state or to constitute a negligible fraction of exports. Commodities with a dollar value but no information on tonnage were retained in the data because the tonnage could be reasonably estimated using the price per ton obtained from the dollar value and tonnage of the commodity going to all destinations.

Before transferring data from Table 12 to an interim spreadsheet, all dashes (indicating no data) were replaced with zeroes. If there was evidence that some flows were not actually zero, remain uncounted, or are different from the estimates provided, additional information was added when the emergy exported in each commodity class was determined. For example, coal exports were determined using Energy Information Administration (EIA) Data. The Commodity Flow Survey provides a summary table (Table 7) of shipments to all states from the state of origin. Note that the top row in this table gives the total dollar value and tonnage of shipments from the state followed by a set of rows for dollar value and tonnage shipments to each state to which the state of origin is shipping. This includes a row for the state of origin itself, which will be referred to as instate shipments from now on.

An export table (see Table D 1.2) with 11 columns was made to use in determining the tonnage exported in various commodity classes. The commodity classes for SCTG, SIC, and NAICS industry classification codes and the approximate conversions used in this paper are shown in Table D1.1. The column headings for the export table are as follows (1) SCTG code, (2) Description of the class, (3) All Destinations Value($ mil), (4) All Destinations Tons(000), (5) $/Ton, (6) Instate Shipments ($ mil), (7) Instate Shipments Tons(000), (8) Known (directly measured) exports Tons(000), (9) Instate Tons (000) estimated using $/T, (10) Estimated exports tons (000), (11) Final Exports (estimated exports are adjusted to sum to the total missing tonnage). . Table D 1.2 omits column 2, the verbal description, because of space considerations.

Table D1.1. Approximate conversion between SCTG , SIC and NAICS industry classification codes developed for this study. These conversions are only approximate and better information might be developed of used if available.

Class	Combined Code	SCTG code	SIC code	NAICS Code
agricultural products, grain	A	2,3	1	111
livestock, seafood, animal products	B	1,4	2,9	112
logs, rough wood	C	25	8	113
metallic ores	D	14	10	2122
coal	E	15	12	2121
non-metallic minerals, gravel, stone, sand	F	11,12,13	14	2123
prepared food products, alcohol, tobacco	G	5,6,7,8,9	20,21	311,312
textiles, leather, apparel	H	30	22,23,31	313
lumber wood product	I	26	24	321
furniture, fixtures	J	39	25	337
paper products	K	27,28	26	322
printed products	L	29	27	323
chemicals	M	20,21,22,23	28	325
refined petroleum products	N	17,18,19	29	324
plastics and rubber	O	24	30	326
building materials, non-metallic	P	10,31	32	327,331
primary metal products, semi-finished	Q	32	33	331
fabricated metal products. Cans etc.	R	33	34	332
machinery (not electrical)	S	34	35	333
electrical equipment , precision instruments	T	35.38	36,38	334,335
transportation equipment	U	36,37	37	336
miscellaneous manufactured goods	V	40	39	339
scrap and waste	W	41	49 (?)	562 (?)
unknown, mixed or special classes	Y	43	92,98,99	99999

The steps in estimating exports from a state, e.g., West Virginia, using the data in the spreadsheet columns described above are as follows:
First, copy the Commodity Class code and description from the Commodity Flow Survey Table 12 (Additional Data) for the state, for which exports are to be calculated Columns (1 and 2). Remember in following the instructions below that column numbers refer to the 11 column headings recommended above. The 10 columns shown in Table D 1.2, which is missing column 2, have been numbered to match the verbal description.

1. Copy the $ value and tons moving from the state to all destinations for all commodities, Columns (3) and (4).
2. Calculate the $ per ton. Column (5)
3. Copy data ($ and Tonnage) for shipments of all commodities with final destination in the state of origin, e.g., from WV to WV, Columns (6) and (7).
4 Calculate known exports by subtracting instate shipments (column 7) from the shipments moving to all destinations (column 4) for all commodities for which tonnage has been measured, directly, Column (8).

5. Sum the tonnage of directly measured export shipments (Column 8) and subtract from the total tonnage moving to all destinations. The total tonnage is given at the top of the All Destinations column in Table D 1.2 and in CFS Table 12.
6. Calculate the tonnage of instate shipments for any commodity for which a $ value of instate shipments is given in column 6 by dividing by the $ per ton (column 5). Record in Column 9 the estimated instate shipments.
7 Estimate the tonnage exported in these commodity classes by subtracting the instate tonnage estimates (column 9) from tonnage moving to all destinations (column 4). Record these estimates in Column 10.
8. Sum the estimated export shipments (column 9) and divide into the difference between directly measured exports and total exports. If this ration equals 1 combine directly measured and estimated exports in their respective commodity classes into a single column (11) and you are done. If greater or less than 1 multiply each estimated commodity by this ratio to adjust the flows so that directly measured and estimated exports will sum to the known tonnage of total exports shipped to all destinations. Record these numbers in Column (11), Final Adjusted Exports, and fill in column with the directly measured values from Column (8).

Table D1.2. Calculation of West Virginia Exports from the state to state commodity shipments found in the Commodity Flow Survey as Additional Data in Table 12.

SCTG Code	All Destinations Value($ mil)	All Destinations Tons(000)	$/ton	Instate Value (mil $)	Instate Tons (000)	Directly Measured Exports	Estimate Instate Tons(000)	Estimate State Exports	Final Adjusted Exports
Col. 1	Column 3	Column 4	Col. 5	Col. 6	Col. 7	Col.8	Col.9	Col. 10	Col. 11
Total	35570	233760		8336	66249	167511			167511
1	-	-	0	-	-	0			0
2	-	-	0	-	-	0			0
3	S	S	356	S	S	S	S		0
4	129	467	276	87	438	29			29
5	609	259	2351	50	21	238			238
6	29	14	2071	20	11	3			3
7	223	S	843	S	S	S	S		0
8	365	351	1040	365	351	0			0
9	440	19	23158	177	7	12			12
10	S	S	94	S	S	S	S		0

Table D1.2 continued

SCTG Code	All Destinations Value($ mil)	All Destinations Tons(000)	$/ton	Instate Value (mil $)	Instate Tons (000)	Directly Measured Exports	Estimate Instate Tons(000)	Estimate State Exports	Final Adjusted Exports
11	32	793	40	4	347	446			446
12	53	5667	9	51	5484	183			183
13	S	S	29	S	S	S	S		0
14	S	S	689	S	S	S	S		0
15	4943	187835	26	1107	44488	143347			143347
17	393	S	272	S	S	S	S		0
18	227	964	235	224	954	10			10
19	532	3335	160	78	163	3172			3172
20	3918	5152	760	425	897	4255			4255
21	1996	S	32716	S	S	S	S		0

22	S	S	216	S	S	S	S		0
23	1512	946	1598	518	290	656			656
24	2582	1316	1962	485	387	929			929
25	370	5627	66	132	S	S	2007	3620	3406
26	900	3869	233	216	1045	2824			2824
27	69	108	639	S	S	S	S		0
28	123	87	1414	58	S	S	41	46	43
29	483	S	2499	S	S	S	S		0
30	S	S	9097	S	S	S	S		0
31	937	5007	187	263	3658	1349			1349
32	4158	6306	659	449	S	S	681	5625	5294
33	860	851	1011	525	465	386			386
34	2109	187	11278	483	48	139			139
35	1326	120	11050	242	S	S	22	98	92
36	2900	519	5588	212	S	S	38	481	453
37	320	S	10622	S	S	S	S		0
38	234	2	117000	S	-	S	S		0
39	159	45	3533	57	12	33			33
40	692	134	5164	140	S	S	27	107	101
41	S	S	148	S	S	S	S		0
43	794	425	1868	605	314	111			111
--	99	38	2605	S	S	S	S		0

Class Totals	158122	9977	167511
Difference (Total - Class Total from Column 7 in this Table.	9389		
Fraction (Difference/Class Total (Column 7/Column 9 this table)	0.941		

Transferring Export Data to the Emergy Evaluation Spreadsheet

Columns 1, 2 and 11 beginning with SCTG code 1, can now be transferred to the emergy export evaluation section. Do not include commodities with zero flow. These are only shown in Table D 1.2 as placeholders to present a complete listing of all commodity categories.

Import Calculations

Table 12 from the CFS web site, "Additional State Data", used in the export calculation, has information on the exports by commodity class going from all the other states to the state of destination (West Virginia). Data from the other 49 states that might be exporting to the study state were combined to determine imports. Inbound shipments by state of origin to the state of destination are summarized in Table 8 of the CFS, but commodity classes are not shown. For states without a U.S. Customs port, state to state commodity shipments will capture almost everything entering the state. When one or more U.S. customs ports are located in a state the foreign imports entering the state need to be added, regardless of whether they are immediately exported to another state. We assume that these imports bring some value to the state by simply passing through.

The inbound tonnage shipped in each commodity category was used to calculate the emergy imported in goods. The five steps used to estimate imported emergy to a state are as follows: (1) a quick tally of the total tonnage coming into the study state from other states was obtained by consulting Table 8 in the CFS report. The states that had a number entered in the percent of total inbound shipments column were identified. The total percentage of imports directly measured was determined by summing the percentages. The total percent of tonnage from the states used to estimate imports should be at least 95% of the tonnage of total inbound shipments. (2) Once the subset of states exporting to the study state was identified, missing values for the tonnage for specific commodities coming from each state were estimated. (3) If a dollar value of the inbound commodity shipments was known and tonnage was not listed, the tonnage was estimated based on the cost per ton as described above and shown in Table D 1.2. A large fraction of total inbound shipments from some states had missing values for both dollar value and tonnage (an S or D entered into the field). In this case, the missing data would have resulted in large errors in the estimate of total imports and thus the development of a method to handle this situation was warranted. The tonnage fields for inbound shipments from a state of origin to West Virginia containing and S or a D were handled by assuming that a state's exports to any other state would on average follow its overall export profile*, i.e.,* the fraction of total shipments accounted for by each commodity. Missing tonnage data was distributed among commodity classes by adjusting the overall export profile. The missing tonnage data is equal to total shipments to West Virginia minus commodities with numeric entries for tonnage. This tonnage was distributed among the commodity classes with inbound shipments by adjusting the state's overall export profile so that the unknown inbound shipments made up 100% of the missing inbound tonnage. (4) The inbound tonnage in each commodity class for a state was transferred as a single column to a second worksheet with data from all of the identified import states. (5) Then each commodity class was summed across the rows for all states to create the column of data with imported tonnages in each commodity class for the emergy table.

1. The following steps describe the estimation of the unknown tonnage (S and D) as illustrated for Alabama's shipments to West Virginia shown in Table D 1.3. For all of the states importing to the study state, copy the total tonnage in each commodity class exported to all destinations and the tonnage exported to the state you are evaluating (columns 2 and 3 in Table D 1.3), onto a spreadsheet..
2. Calculate the price per ton for all inbound shipments by commodity class from any state exporting to the study state according to the instructions given above for exports.
3. Replace all dashes with a zero. Although Table D 1.3 only presents one state, the same procedure will be used for all states sending a significant quantity of imports to the study state.
4. Next, missing tonnage values are estimated for any commodity class that reported a dollar value of exports to the state but no tonnage. In some cases calculating the price per ton for the state of origin is not possible, but there is still a dollar value for exports. Prices per ton can be quite variable but find an adjacent state (or use a better estimation method) and substitute this price in the spreadsheet making a note on its origin. Fill in all tonnage movements possible using this method. Combine the tonnages estimated on the basis of average price with the tonnages that were directly measured. Sum this column and subtract from the total tonnage exported to the study state to get the tonnage that will be distributed using the export profile (see the number in italics at the top of column 4 in Table D 1.3). For example, the total export from Alabama to West Virginia is 318 thousand tons but the sum of all commodities determined directly and estimated based on dollar value only adds up to 27 thousand tons, the difference is then 291 thousand tons.
5. Create a fourth column for the export profile, which will be used to distribute the missing tonnage across the remaining commodities that had either an S or D in both the dollar value and tonnage fields. The export profile is the fraction of the total tonnage accounted for by each commodity as determined from the shipments to all destinations. Calculate the profile by dividing the tonnage for each commodity exported by the total tonnage exported for that state. Only those

commodities that have an S or D in both dollar value and tonnage fields are recorded in column 4. Sum the fractions to determine the fraction of total tons accounted for by the commodities with missing data.

6. The next step is to adjust these fractions to represent the expected fractions of the missing tonnage imported to the state in each commodity class with missing data. Create a fifth column, the adjusted fraction of missing tonnage imported in each class, where each fraction of the tons in the export profile (individual values in column 4) will be divided by the fraction of the total tons that is missing (the sum of all fractions in column four). The sum of all values in column 5 should equal one, or 100%.
7. In the last column (column 6), copy over the reported and estimated data for tonnage for any commodity where it is available from column 3. For all of the missing commodities (those with and S or D in both the $ value and tonnage fields), multiply the total missing tonnage (at the top of Column 4) by the corresponding percentage (in Column 5) for each commodity class known to have a flow but for which tonnage is unknown, and transfer this number to the appropriate field in column 6. For example, if data is missing for textiles, multiply 291 thousand tons by the fraction of textiles or 0.0172, to get 5 thousand tons textiles imported. Sum this column to make sure it adds up to the total tonnage.
8. Transfer this tonnage data for each commodity to an import table creating a column for each state.
9. Sum across the states (rows) for each commodity to find the total tonnage imported in each commodity class and transfer this to the import section of the emergy evaluation.

Custom's Imports

If the state has a Customs' port, locate the appropriate data on the USITC data web site (37). The Customs' site requires a password, but registration is free. To get the correct data report, a series of dialogue boxes must be completed. The choices that should be made are as follows:

- Dialogue 1 – U.S. General Imports; NAICS code; current US Trade
- Dialogue 2 – Customs value; 1997; All import commodities; All countries; All country sub-codes; create new district list
    - Enter the name, select the districts, then highlight the name when you return to original page;

  In 1,000,000; annual; NAICS 3 digit; aggregate all countries together; aggregate import programs; display districts separately
- Dialogue 3 – Arrange in this order: District; NAICS 3
- Dialogue 4 – District; General customs value; Show all; Sort 1997; 5000 records; other display options are optional

Use Table D1.1 or better conversion system to convert from NAICS to SCTG code. Create a column for this data and include it in the summation of imports described in step 9 above.

Table D1.3: Example of estimating missing import data. Alabama to West Virginia

Description	Total Tons from Alabama (thousands)	Tons to WV (thousands)	Fraction of total tons for missing data	Fraction of missing tonnage to WV	Total Tons to WV (thousands)
All commodities	256234	318	*291*		
Live animals and live fish	125	-			0.0
Cereal grains	S	-			0.0
Other agricultural products	1682	-			0.0
Animal feed and products of animal origin	7194	S	0.028	0.059	17.2
Meat, fish, seafood, and their preparations	1836	S	0.007	0.015	4.4

Milled grain and bakery products	386	S	0.002	0.003	0.9
Other prepared foodstuffs and fats and oils	4408	S	0.017	0.036	10.5
Alcoholic beverages	482	-		0.000	0.0
Tobacco products	51	S	0.000	0.000	0.1
Monumental or building stone	S	-		0.000	0.0
Natural sands	S	-		0.000	0.0
Gravel and crushed stone	36211	-		0.000	0.0
Nonmetallic minerals	2905	S	0.011	0.024	6.9
Metallic ores and concentrates	S	-		0.000	0.0
Coal	30993	-		0.000	0.0
Gasoline and aviation turbine fuel	12659	-		0.000	0.0
Fuel oils	3605	-		0.000	0.0
Coal and petroleum products,	4671	S	0.018	0.038	11.1
Basic chemicals	7460	S	0.029	0.061	17.8
Pharmaceutical products	33	S	0.000	0.000	0.1
Fertilizers	2382	S	0.009	0.020	5.7
Chemical products and preparations	1271	S	0.005	0.010	3.0
Plastics and rubber	1585	S	0.006	0.013	3.8
Logs and other wood in the rough	40817	S	0.159	0.334	97.3
Wood products	12443	S	0.049	0.102	29.7
Pulp, newsprint, paper, and paperboard	8949	S	0.035	0.073	21.3
Paper or paperboard articles	977	-		0.000	0.0
Printed products	324	S	0.001	0.003	0.8

Table D1.3 continued

Description	Total Tons from Alabama (thousands)	Tons to WV (thousands)	Fraction of total tons for missing data	Fraction of missing tonnage to WV	Total Tons to WV (thousands)
Textiles, leather, and articles of textiles or leather	2120	S	0.008	0.017	5.1
Nonmetallic mineral products	16613	S	0.065	0.136	39.6
Base metal in primary or semi finished forms and in finished basic shapes	11212	17			17.0
Articles of base metal	4208	S	0.016	0.034	10.0
Machinery	753	1		0.000	1.0
Electronic and other electrical equipment and components and office equipment	688	S	0.003	0.006	1.6
Motorized and other vehicles (including parts)	957	S	0.004	0.008	2.3
Transportation equipment	251	S	0.001	0.002	0.6
Precision instruments and apparatus	10	-		0.000	0.0
Furniture, mattresses and mattress supports, lamps, lighting fittings, and...	501	S	0.002	0.004	1.2
Miscellaneous manufactured products	2965	9			9.0
Waste and scrap	2130	-			0.0
Mixed freight	2000	-			0.0
Commodity unknown	S	-			
subtotals to check		27	0.476	1.000	318

D2. The Method for Calculating Services Imported and Exported

In this study, we adapted the base-nonbase method from economics to estimate the emergy of pure services imported and exported from West Virginia or any other state. This method was first used in an emergy analysis by Odum et al. (1998) and we used that work as a starting point. The theory and formulae for estimating services are given in the methods section above. There follows a detailed description of how we estimated exported and imported services. This material is given so that our method will be transparent and reproducible and therefore easier to refine and improve.

To determine exported and imported services, go to the NAICS economic sector data U.S. data *(31)* and then choose the state from the menu in the upper left-hand corner. You will also need agricultural and government data not given in *(31)*. Government expenditures by state are available in the U.S. Statistical Abstract for 1997 (also online). Agricultural data can be obtained from Economic Research Service, USDA Data- Farm and Farm-Related Employment *(38)*. These instructions create one large table comparing all of this data, but if smaller pieces are preferred, use a method that makes sense as long as the basic guidelines are preserved.

A) Using the list of non-farm industries given by NAICS two digit industry codes and recorded on the U.S. Census Bureau web site, there are 18 industry sectors (Table D 2.1), to which agriculture and government should be added. This table will be used to classify each sector as base or non-base. As mentioned in the services section of the main paper, base sectors are those that will have enough production to export, while non-base sectors are more likely to serve the local (state) economy. Agriculture, manufacturing, mining, and state and federal government are sectors that are often considered to be basic sectors. In the case of West Virginia, the utilities industry was added because it exports a large fraction of the electricity produced. Non-basic industries provide mostly local services such as support services and the retail industries like grocery stores, dry cleaners, drug stores etc. The data for each state should be examined and each of the 20 industry sectors designated as basic or non-basic industries using a set of initial assumptions. Since this method is only used to determine <u>services</u> imported and exported, each industry category must be further considered from this point of view. For example, in West Virginia exports from the manufacturing and agriculture sectors are almost entirely goods (this can be verified by examining the more detailed listing of higher digit industry sectors in the U.S. Census Bureau listing by NAICS code, see web site given above), the service component of which is determined below. In addition the mining and utilities sectors also are largely goods exporting sectors, however, each of these sectors has a service component. To accurately estimate the exports from these two sectors the detailed level of NAICS industry categories was used. This information is available at the same web address *(31)*. For example, within the mining sector there is a category for mining support activities. For West Virginia this category includes classes for drilling oil and gas wells, support activities for oil and gas operations and support activities for coal mining. All three of these are sources of potentially exportable services. The detailed code data should be used when it is needed for the particular economic situation in a given state. However, the two digit data can be used where the entire sector provides services for export or that might be imported. Table 1 gives a list of the 20 two digit industry categories and the assumptions that were made about them for West Virginia.

B) In the second table, the 20 sectors become the column headings and the data and calculations using this data are the rows. Table D 2.2 presents an abbreviated version of the total table (See Appendix C for the complete West Virginia table). The following steps are the same for calculating values for all columns, or sectors, and match the note numbers in Table D 2.2; however, you might want to complete rows 15 and 16 first. An explanation of the rows in Table D 2.2 follows:

    1) U.S Paid employees. This number is from either the U.S. census table or one of the other two sites listed above for agriculture and government.

2) U.S. Sales, Receipts or Shipments ($1000). This number is from either the U.S. census table or one of the other two sites listed for agriculture and government.
3) U.S. Dollars per employee. Divide row 2 by row 1 and multiply by 1000.
4) U.S. Fraction of Total Employment. Divide row 1 by the value for line 15 (see note 15).
5) State Paid employees. This number is from either the WV census or from one of the other two sites listed above for agriculture and government.
6) State Sales, Receipts or Shipments ($1000).This number is from either the WV census or from one of the other two sites listed above for agriculture and government

Table D2.1. NAICS industry sectors and their assumed sector types for WV.

Industry	Sector Type	Notes
Agriculture	Basic-export	all goods
Mining	Basic-export	Support activities (only)
Utilities	Basic-export	Electric services (only)
Construction	Nonbasic	Local markets
Manufacturing	Basic	All goods
Wholesale trade	Nonbasic	Local markets
Retail trade	Nonbasic	Local markets (no export)
Transportation & Warehousing	Nonbasic	Local markets
Information	Nonbasic	Potentially imported
Finance &Insurance	Nonbasic	Potentially imported
Real estate & rental	Non-basic	Local markets
Professional, scientific services	Non-basic	Potentially imported
Management of companies	Non-basic	Potentially imported
Administrative support & waste management	Non-basic	Potentially imported
Educational services	Non-basic	Potentially imported
Health care and social assistance	Non-basic	Local markets (no export)
Arts, entertainment & recreation	Non-basic	Potentially imported
Accommodation and food service	Basic	not imported or exported
Other services (not public)	Nonbasic	Local markets
Auxiliaries	Non-basic	Local markets
Government	Basic	not exported

Table D2.2. Calculation of basic sector jobs and the estimated dollar values for exported and imported services.

Assumed sector behavior from Table 1		base	non-base
Note	Item	Mining	Constr
1	U.S Paid employees	509006	5664840
2	U.S. Sales, Receipts or Shipments ($1000)	173988778	858581046
3	U.S. Dollars per employee	341820.68	151563.16
4	U.S. Fraction of Total Employment	0.004094585	0.04556954
5	State Paid employees	23927	31312
6	State Sales, Receipts or Shipments ($1000)	6333463	3106093
7	State Dollars per employee	264699.42	99198.17
8	State Fraction of Total Employment	0.034013838	0.04451211
9	Location Quotient	8.31	0.98
10	Sector ratio of regional to national employment	0.05	0.01
11	National ratio of regional to national employment	0.01	0.01
12	Basic sector jobs	2.10E+04	-7.44E+02
13	Potential state services export/import	5.57E+09	-7.38E+07
14	State services export (+) or import (-)	1.02E+08	-3.69E+07

15	Total U.S. employment, all sectors plus agriculture and government	124311992
16	Total WV employment, all sectors plus agriculture and government	703449

Estimation of services actually exported using data for the entire mining sector.

14' More detailed sector data that separates out service components may also be used

Total non-service mining receipts, WV	6,021,285,000
Total non-service mining employment, WV	20983
Total non-service mining employment, US	340200
Fraction total employment, WV	0.0298
Fraction total employment, US	0.00274
Location quotient	10.90
Non-service $/employee, WV	286,960
Sector ratio of regional to national employment	0.0617
National ratio of regional to national employment	0.00566
Basic sector jobs	19058
Material export	5,468,857,228

7) State Dollars per employee. Divide row 6 by row 5 and multiply by 1000.
8) State Fraction of Total Employment. Divide row 5 by line 16 (see note 16).
9) Location Quotient. Divide row 8 by row 4. If this number is >1 the state is able to export a portion of this sector's productivity.
10) Sector ratio of regional to national employment. Divide row 5 by row 1.
11) Ratio of regional to national employment. Divide row 16 by row 15. This is a constant across all sectors and is an indication of the overall available workforce, regional to national.
12) Basic sector jobs. The number of basic jobs in a sector is found by subtracting the fraction of national employment in the region from the fraction of regional sector employment in the national sector, and then multiplying by national employment in the sector. Subtract row 11 from row 10 and multiply the difference by row 1. A positive number indicates an exporting sector and a negative number indicates a potential importing sector. However, the original assumptions about sector behavior will determine whether the potential for export or import is realized.
13) Exported goods and services are determined by multiplying the regional sector productivity per worker by the number of workers in the basic part of the sector. In other words, multiply row 12 by row 7 unless the initial assumptions about this sector make it a non-basic or non-exporting sector. Potential imports are determined by multiplying the national sector productivity per worker by the deficit number of workers for the sectors importing services. Multiply a negative value in Row 12 by the value in row 3.
14) Exports are corrected by subtracting the services in exported goods from the potential exports of a sector. For West Virginia this was done for two sectors – mining and utilities. Other basic sectors were shown to either not export or to export only goods. The dollar value of goods exported from the sector must be subtracted form the total exports obtained in 13 to get an estimate of the services exported. For example, the dollar value of electricity exported could be subtracted from the utility sector exports estimated in 13 to get an estimate of the value of electrical services exported. We also estimated services exported by an alternative method. To use this method, step down one level of information into the structure of the exporting sector. Detailed information for these sectors is available (click on the arrow next to the sector in the main tables). Using this data, complete the same procedure used above for the pure service components of the sector to determine services exported directly. These estimates are totaled and constitute the estimate for exported services when summed over all basic sectors that export. The emergy in the goods exported could also be determined by performing the location quotient analysis on the sub-sectors that are exporting goods. The sum of these export estimates can then be subtracted from the total in 13 to give a remainder that is the estimate of exported services. To estimate the actual imports, we assumed that a fraction of the potential import (a negative amount on line 13) equal to the ratio of West Virginia's per capita income to national per capita income is actually imported into the state as explained above. Sum the positive values for exported services and the negative values for imported services, respectively. These totals are transferred to the import/export tables in the emergy evaluation for total services
15) For 1997 studies of U.S. states, the number provided here can be used for the national totals. It is the total employment for all sectors including agriculture and government.
16) West Virginia total employment in 1997 is the sum of employment in all sectors mentioned above.

Appendix E.

West Virginia Emergy Accounts for 2000.

Table E1
Renewable Resources and Production in the West Virginia Economy in 2000.

Note	Item	Data J, g, $, ind/yr	Units	Emergy/Unit sej/unit	Emergy E20 sej	2000 Emdollars E6 Em$
	Renewable Resources within West Virginia					
1	Sun, incident	3.074 E+20	J	1	3	287
1	Sun, absorbed	2.644 E+20	J	1	3	247
2	Wind	3.580 E+17	J	1470	5.3	439
3	Earth Cycle	1.388 E+17	J	33700	47	4372
4	Rain, chemical potential energy received	3.323 E+17	J	18100	60	5621
5	Evapotranspiration, chemical potential absorbed	1.561 E+17	J	28100	44	4099
6	Rain, geo-potential on land	3.655 E+17	J	10300	38	3518
7	Rain, geo-potential of runoff	6.024 E+16	J	27200	16	1531
8	Rivers, chemical potential energy received	9.056 E+16	J	50100	45	4240
8	Rivers, chemical potential energy absorbed	2.896 E+14	J	50100	0.15	14
9	Rivers, geo-potential energy received	4.987 E+16	J	27200	14	1268
9	Rivers, geo-potential energy absorbed	2.058 E+16	J	27200	5.6	523
	Renewable Production within West Virginia					
10	Agricultural Products	5.340 E+16	J	50000	27	2495
11	Livestock					
	Beef	6.932 E+14	J	680000	4.7	441
	All other livestock	3.970 E+14	J	792000	3.1	294
12	Fish Production	7.099 E+11	J	1961800	0.14	1
13	Hydroelectricity	1.092 E+16	J	120300	13	1228
14	Net Timber Growth	2.096 E+17	J	20600	43	4035
15	Timber harvest	2.286 E+16	J	68700	16	1468
16	Ground water	9.493 E+14	J	159000	1.5	141

Table E2
Production and Use from Nonrenewable Sources within West Virginia in 2000.

Note	Item	Data J, g, $, ind/yr	Units	Emergy/Unit sej/unit	Emergy E20 sej	2000 Emdollars E6 Em$
Fuels and renewables used in a nonrenewable manner						
17	Coal Production	4.22 E+18	J	39200	1654	154,601
18	Coal Used in the State	1.03 E+18	J	39200	404	37,735
19	Natural Gas Production	2.91 E+17	J	47100	137	12,809
20	Natural Gas Used in the State	1.60 E+17	J	47100	75	4,043
21	Petroleum Production	9.50 E+15	J	53000	5	471
22	Petroleum Used in the State	2.26 E+17	J	64700	146	13,666
23	Electricity Production	3.40 E+17	J	170400	579	54,146
24	Electricity Used in the State	9.78 E+16	J	170400	167	15,607
25	Clay	3.40 E+05	T	1.9 E+15	6.5	604
26	Sand and Gravel	1.9 E+06	T	1.3 E+15	24.7	2,308
27	Limestone	1.2 E+07	T	9.8 E+14	118	10,991
28	Sandstone	1.0 E+06	T	9.8 E+14	10	916
29	Soil Erosion of agricultural areas	4.0 E+15	J	72600	3	271

Table E3
Imports to the West Virginia Economy in 2000.

Note	Item	Data J, g, $, ind/yr	Units	Emergy/Unit sej/unit	Emergy E20 sej	2000 Emdollars E6 Em$
30	Coal	2.30 E+17	J	39200	90	8,426
31	Petroleum	2.16 E+17	J	64700	140	13,060
32	Natural Gas (Received at state boarder)	1.58 E+18	J	47100	744	69,550
33	Iron Ore	4.41 E+13	J	6.08 E+07	27	2,506
34	Alumina/Bauxite	4.4 E+13	J	1.47 E+07	6	604
35	Services Embodied in the Goods	2.50 E+10	$	1.07 E+12	268	25,000
36	Material in the Goods	Various	J or g	Various	948	77,705
37	Services	6.2 E+09	$	1.07 E+12	663	62,000
38	Federal Government	1.07 E+10	$	5.79 E+12	620	57,900

Table E4
Exports from the West Virginia Economy in 2000.

Note	Item	Data J, g, $, ind/yr	Units	Emergy/Unit sej/unit	Emergy E20 sej	2000 Emdollars E6 Em$
39	Coal	3.19 E+18	J	39200	1250	116,867
40	Natural Gas (Production Exports)	1.20 E+17	J	47100	57	5,282
41	Natural Gas (Delivered at state border)	1.75 E+18	J	47100	824	77,032
42	Electricity	2.42 E+17	J	170400	412	38,539
43	Steel	2.00 E+12	g	3.38 E+09	68	6,317
44	Services Embodied in the Goods	2.72 E+10	$	1.07 E+12	291	27,200
45	Material in the Goods	Various	J or g	Various	776	72,523
46	Services	5.80 E+08	$	1.07 E+12	6	580
47	Migration (total)	2660	People	Various	4.2	344
	Preschool	876	People	3.3 E+16	0.3	24
	School	1188	People	9.2 E+16	1.1	90
	College Grad	479	People	2.7 E+17	1.29	106
	Post-College	117	People	1.3 E+18	1.5	125
48	Tourism	4.0 E+09	$	5.79 E+12	232	21,682
38	Federal Taxes Paid	6.1 E+09	$	5.79 E+12	353	32,990

Table E5
Value of West Virginia Storages in 2000.

Note	Item	Data J, g, $, ind/yr	Units	Emergy/Unit sej/unit	Emergy E20 sej	2000 Emdollars E6 Em$
49	Forest	1.04 E+19	J	28200	2933	274,093
50	Coal	1.42 E+21	J	39200	556640	52,022,429
51	Petroleum	1.19 E+17	J	53000	63	5,894
52	Natural Gas	3.13 E+18	J	47100	1474	137,779
53	People 2000 population	1,808,344	Ind.		3908	365,394
	Preschool	21,635	Ind.	3.3 E+16	7	667
	School	1,164,463	Ind.	9.2 E+16	1071	100,122
	College Grad	384,232	Ind.	2.7 E+17	1037	96,955
	Post-College	56,266	Ind.	1.3 E+18	731	68,360
	Elderly (70+)	163,101	Ind.	1.7 E+17	277	25,913
	Public Status	18,568	Ind.	3.9 E+18	724	67,678
	Legacy	792	Ind.	7.7 E+18	61	5,699

Table E6
Summary of Flows for West Virginia in 2000.

Note	Letter in Fig. 2	Item	Emergy E20 sej	1997 Dollars E+09 $/yr	2000 Emdollars E+09 Em$/y
54	R_R	Renewable emergy received	105		9.82
54	R_A	Renewable emergy absorbed	66		6.17
55	N	Nonrenewable source flows	1958		182.99
56	N_0	Dispersed Rural Source	3		0.28
57	N_1	Mineral Production (fuels, etc.)	1955		182.71
58	N_2	Fuels Exported without Use	1312		122.62
59	F	Imported Minerals (fuels, etc.)	263		24.58
60	F_1	Minerals Used ($F+N_1-N_2$)	906		84.67
61	F_2	In State Minerals Used (N_1-N_2)	643		60.09
62	G	Imported Goods (materials)	948		88.60
63	I	Dollars Paid for all Imports		31.13	
64	I_1	Dollars Paid for Service in Fuels		1.72	
65	I_2	Dollars Paid for Service in Goods		23.24	
66	I_3	Dollars paid for Services		6.17	
67	I_6	Federal Transfer Payments		10.7	
68	PI	Imported Services Total	375		35.05
69	PI_1	Imported Services in Fuels	21		1.96
70	PI_2	Imported Services in Goods	280		26.17
71	PI_3	Imported Services	74		6.92
72	PI_4	Emergy purchased by Federal $	620		57.94
73	B	Exported Products (goods + elec.)	1188		111.03
74	E	Dollars Paid for Exports		31.08	
75	E_1	Dollars Paid Fuel Exported		3.92	
76	E_2	Dollars Paid for Goods		26.6	
77	E_3	Dollars Paid for Exported Services		0.58	
78	E_4	Dollars Spent by Tourist		4.0	
79	E_5	Federal Taxes Paid		6.1	
80	PE	Total Exported Services	379		35.42
81	PE_1	Exported Services in Fuels	48		4.49
82	PE_2	Exported Services in Goods	324		30.28
83	PE_3	Exported Services	7		0.65
84	PE_4	Emergy Purchased by Tourists	237		22.15
85	PE_5	Emergy Purchases Forgone	353		32.99
86	X	Gross State Product		39.7	